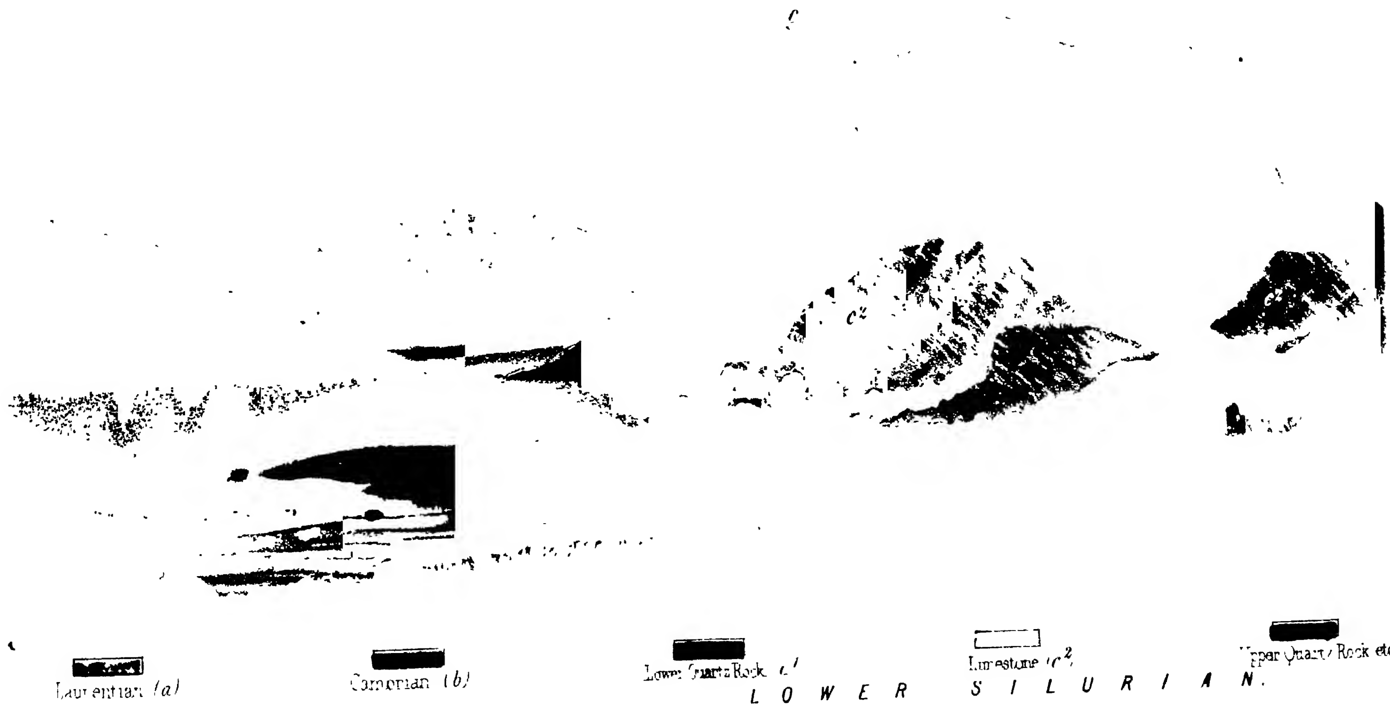


Vincent Brooks, lith

[illegible] AND QUEENAIG MOUNTAIN FROM INCHNADAMFF

"The men who begin with speculation and end with facts begin at the wrong end; the firmest materials should be in the foundation."—SIR HUMPHRY DAVY.

"The crust of the earth is a great cemetery, where the rocks are tombstones on which the buried dead have written their own epitaphs."—AGASSIZ.

SILURIA.

A HISTORY OF

THE OLDEST ROCKS IN THE BRITISH ISLES

AND OTHER COUNTRIES;

WITH SKETCHES OF THE ORIGIN AND DISTRIBUTION OF NATIVE GOLD,
THE GENERAL SUCCESSION OF GEOLOGICAL FORMATIONS,
AND CHANGES OF THE EARTH'S SURFACE.

BY SIR RODERICK I. MURCHISON, BART., K.C.B.,

LATE DIRECTOR GENERAL OF THE GEOLOGICAL SURVEY OF THE BRITISH ISLES;
PRESIDENT OF THE ROYAL GEOGRAPHICAL SOCIETY OF LONDON,
ETC., ETC.

FIFTH EDITION.

WITH MAP AND TWO HUNDRED ILLUSTRATIONS.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1872.

Dedication.

TO

SIR WILLIAM LOGAN, LL.D., F.R.S., F.G.S.,

DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY OF CANADA,

I DEDICATE THIS NEW EDITION OF

SILURIA.

The original 'Silurian System' having been dedicated to my eminent associate, PROFESSOR SEDGWICK, *the earliest Edition of this Work was dedicated to my predecessor in office,* SIR HENRY T. DE LA BECHE, *who first adopted the use of the Silurian Classification in the publications and maps of the Geological Survey of Britain.*

The last Edition was naturally inscribed to my valued cotemporaries, E. DE VERNEUIL, A. VON KEYSERLING, *and* JOACHIM BARRANDE, *by whose labours the Silurian System has been successfully extended to various parts of the world.*

I now dedicate this Volume to the Geologist who has not only applied my classification to the vast regions of British North America, but has taught us by his recent important researches that the Laurentian Rocks constitute the foundation-stones of all Palæozoic deposits in the crust of the Globe, wherever their Foundations are known.

RODERICK IMPEY MURCHISON.

Belgrave Square, London,
July 10, 1867.

PREFACE.

The term 'Silurian,' when first applied by me in 1835 (and in my large work, entitled the 'Silurian System,' completed in 1838), was intended to characterize a great natural system of ancient deposits which had not before been classified, and the type of which was found to be exhibited in *Siluria*, or the country of Caractacus and the old Britons known as 'Silures.' The name of 'Siluria' has also been given to the preceding and present editions of this volume, descriptive not only of the Silurian rocks, but all the Palæozoic deposits, from the earliest in which traces of life have been discovered. The important additions made to our knowledge respecting these ancient deposits within the last eight years have induced me to prepare this new edition, in which, by the use of a smaller type, a great amount of new matter has been included without increasing the size of the volume.

The most important of these additions is the discovery, made by Logan and his associates in British North America, of an organic body in the old gneissic Laurentian or bottom-rocks of that region. The existence of these, the most ancient of all stratified deposits, beneath the Cambrian and Lower Silurian rocks of the North-west of Scotland, as first proved by my own labours, was announced in the last edition, when it was illustrated by the coloured Frontispiece now reproduced.

The early portion of this volume has been enriched by knowledge derived from Professor Ramsay's work on the Geology of North Wales, wherein that author and his associates of the Geological Survey have, after long and skilful researches, most successfully developed the details and structure of the most complicated and diversified of all the Silurian tracts of Britain. In the same volume Mr. Salter, who aided me so essentially in bringing out the earlier editions of 'Siluria,' has, with his recognized ability, described several new species, the position of many of which he had noted *in situ*.

The very remarkable work by Mr. Thomas Davidson on the Silurian Brachiopoda of Britain, the result, like several other of his publications, of many years of matured and critical study and comparison, has already

been of great service to me. This work, when complete, will leave nothing to desire in respect to this great division of the British Silurian Fauna,—a group most useful to the field-geologist, who must ever be to a great extent dependent on this class of fossils, on account of their more frequent occurrence than other animal remains. As founder of the 'Silurian System,' I naturally feel highly honoured that Mr. Davidson should have dedicated this work to me, and that he should have invited me to write an Introduction to the Monograph published by the Palæontographical Society.

The last volume brought out by M. Barrande has prominently exhibited the skill of that eminent palæontologist in the great additions he has made to the number and variety of forms, particularly of the Cephalopoda, in his rich and classical 'Bassin Silurien de Bohême;' and it has therefore been my earnest endeavour to do justice to the highly valuable additions made by him.

These labours of my cotemporaries are about to be augmented by a comprehensive and very useful publication of the veteran geologist Dr. Bigsby, who, with unwearied assiduity and acumen, has tabulated the results of the labours of palæontologists of various countries, and combined them with his own extensive observations on the Silurian rocks of North America, in his work 'Thesaurus Siluricus.'

The mere mention of these productions indicates the large additions that have been made to our acquaintance with the animal life of the remote Silurian era. These works have naturally cheered me, inasmuch as they one and all support the name and classification which I proposed so many years ago, after long researches in England and Wales.

Numerous other improvements have indeed been made in this edition of 'Siluria.' Among the most notable in respect to England, are the proofs, as established by Professor Harkness, that no deposit in the slaty region or Lake Country of Cumberland is of higher antiquity than the Lower Llandeilo formation, though the previous belief was that the oldest of those rocks was more ancient than anything Silurian. Again, large tracts in Westmoreland, previously mapped as New Red Sandstone, are now classed with the Permian deposits, as proved by the researches of Professor Harkness and myself. I have further endeavoured to synchronize more perfectly certain rocks in the south-west of Ireland with the Lower Devonian rocks of West Somerset and North Devon, and have, as formerly, referred what used to be called the Old Red Sandstone by Sir R. Griffith and the earlier geologists in Ireland, to the upper member only of the Devonian or Old Red system.

The Permian rocks of Ayrshire, the Scotch Coal-fields, and the structure of the Pentland Hills, have been elucidated by the recent researches of Mr. Geikie, now Director of the Geological Survey of Scotland, as shown by his descriptions and sections illustrating this new edition.

It is unnecessary now to repeat the expression of my obligation to various persons who assisted me, either in the preparation of the 'Silurian System' or the previous editions of this work; for allusions are made to them in the body of the text, and these things are now part of scientific history.

I have, however, a grateful and essential duty to perform, in stating that on this occasion I owe most to my accomplished friend Professor Rupert Jones, who has indeed been of vast service to me, as a well-read geologist and palæontologist, and without whose skilful editorial aid in the preparation of this volume many essential additions would have escaped me.

To Mr. Robert Etheridge, the Palæontologist of the Geological Survey, I am also largely indebted, not only for the support which he has given to the Devonian classification of Sedgwick and myself, by his Memoir on North Devon*, but specially for having enriched the Table of Fossils in the Appendix, originally prepared by Mr. Salter, by the enumeration of nearly three hundred additional British species, many of them having been determined by the last named author. Mr. Etheridge has also, throughout the work, assigned their present names to numerous fossils.

The reader will observe that, in the Tabular List of Silurian Fossils, I have used the term 'Primordial Silurian,' instead of 'Lingula-flags,' the latter having only a local English meaning; and as Lingulæ occur in all formations, from the oldest Silurian to the present day, I have ceased to use the name: moreover some of these old Lingulidæ are now regarded as not being true Lingulæ. The term 'Primordial,' first applied by M. Barrande to the base of the Silurian series in Bohemia, has thus been adopted as generally meaning the lowest Silurian zone, whether it be applied to the Alum-slates of Sweden and Norway, the Lingula-flags of Britain, or the Potsdam Sandstone of North America.

In noticing the advances made in other countries, I have to acknowledge the more exact determination of Palæozoic rocks in Spain by de Verneuil, the late Casiano de Prado, and M. Collomb, and of the older Palæozoic rocks in Norway by the last researches of Kjerulf and Dahll; also many contributions by de Verneuil, Barrande, Logan, Dawson, Helmersen, and other cotemporaries.

In the Chapter on the origin of Gold in the crust of the globe, I have been furnished with new data as respects the two great auriferous regions of Australia and America—the former by Mr. Selwyn, and the latter by Mr. David Forbes. On this head, although I have had reason to modify a broad view put forth in former editions, yet I sustain the same leading opinions as before concerning the origin of the noble metal, its main persistence in certain rocks, and its absence from all unaltered Secondary rocks. In some conglomeratic Tertiary deposits, however, formed out of auriferous Palæozoic rocks, gold necessarily occurs, just as it does in more recent alluvia.

* Read before the Geological Society, April 1867.

In regard to the general Palæozoic Classification here put forward, I gladly avail myself of the opportunity to acknowledge how much I have been gratified by the perusal of the recent work, 'Géologie et Paléontologie,' of the Vicomte d'Archiac. In that truly philosophic history of the progress and actual state of our science, M. d'Archiac has clearly indicated the value of the step which was gained by reducing to method and order the former chaotic assemblages of rocks which passed under the names of 'grauwacké' and 'transition' rocks—an effort, let me say, which could not have been successfully carried out and applied to great foreign regions had I not been so well aided by his associate in the French Institute, my valued friend de Verneuil.

Lastly, after taking a general view of the history of the different races of animals which have succeeded to each other during all geological periods, I have, in the last Chapter, added a brief sketch of my long-cherished convictions respecting many of the former physical and mechanical changes of the earth's surface, as contrasted with any movements which have taken place in historical times. This, however, is a theoretical subject, on which differences of opinion necessarily exist. The view I take of such physical changes is, indeed, entirely apart from my main object, and may either be adopted or set aside without affecting in any way the truthfulness of the Succession of Races in Geological History as described in this volume.

July 10, 1867.

TABLE OF CONTENTS.

CHAPTER I.

INTRODUCTION.

CHAPTER II.

CAMBRIAN ROCKS.

CHAPTER III.

LOWER SILURIAN ROCKS.

CHAPTER IV.

LOWER SILURIAN ROCKS (*continued*).

CHAPTER V.

LLANDOVERY ROCKS (TRANSITION FROM LOWER TO UPPER SILURIAN).

CHAPTER VI.

UPPER SILURIAN ROCKS.

CHAPTER VII.

UPPER SILURIAN ROCKS (*continued*).

CHAPTER VIII.

SILURIAN ROCKS OF BRITAIN

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

Carboniferous Rocks.

CHAPTER XIII.

Permian Rocks.

CHAPTER XIV.

CHAPTER XV.

Primeval Succession in Germany.

CHAPTER XVI.

Palæozoic Rocks of the Harz, the Rhenish Provinces of Prussia, and Belgium.

CHAPTER XVII.

CHAPTER XVIII.

Succession of Primeval Rocks in America.

CHAPTER XIX.

CHAPTER XX.

APPENDIX.

LIST OF ILLUSTRATIONS.

WOODCUTS.

The **Map** and **Figures** of **Fossils** are issued as a separate **Volume**.

NOTICE.

(TO PRECEDE THE FOURTH EDITION OF 'SILURIA.')

THE reader of this edition will find that a very important change has been made in my views as given in former editions, respecting the age of the Upper Sandstones of Elgin and Ross-shire, which I have hitherto classed with the Devonian or Old Red Sandstone. My previous conclusion was founded entirely on the strong natural evidence presented, to me, by the conformable superposition of those beds to the strata of the inferior and unequivocal Old Red Sandstone replete with its well-known fossils. This opinion was confirmed by the examination of the rocks in question by Professor Ramsay, Professor Harkness, the Rev. George Gordon, the Rev. J. M. Joass and others.

The existence, in strata of Devonian age, of reptiles of so high a class as the Telerpeton (see fig. 73 in my last edition, p. 289) and the Stagonolepis was not, indeed, admitted by me without great reluctance, inasmuch as, if eventually substantiated, it would have weakened the main argument that runs through all my writings, which shows a regular progression from lower to higher grades of animals, in ascending from the older to the younger formations. Most joyfully, therefore, did I welcome the remarkable identification by Professor Huxley of the Hyperodapedon of the New Red Sandstone of Warwickshire with the Hyperodapedon of Elgin; and bowing, as I have always done, to clear palæontological proof, I have now excluded all that portion of my former editions which placed these reptiles in the Old Red Sandstone.

The importance of this rectification, due to my eminent associate, has very recently received a wide extension; for among the fossil remains collected in India by the late Rev. S. Hislop, Professor Huxley has also found the Hyperodapedon.

The formation in India containing this reptile has been considered by Professor Oldham, the Director of the Indian Geological Survey, to be either the Trias (New Red Sandstone) or the representative of an intermede between the Palæozoic and Mesozoic rocks. In all probability this correlation will have to be extended to South Africa, since one of the characteristic fossil reptiles of that country, the Dicynodon, has been found in the Ranigunj beds of this age in India.

I take this opportunity of further stating that I have not adverted in the Preface to a great number of important additions which I have made in this edition; they are, in fact, so numerous that if a smaller type had not been used, the work would have been swollen to an unreadable size.

RODERICK I. MURCHISON.

Oct. 30, 1867.

SILURIA.

CHAPTER I.

INTRODUCTION.

A GLANCE AT THE PROBABLE EARLIEST CONDITION OF THE EARTH.—STRATIFIED CRYSTALLINE ROCKS RESULTING FROM CHANGES OF SEDIMENTARY DEPOSITS.—THE SILURIAN SYSTEM ESTABLISHED AND EXTENDED.—THE LAURENTIAN THE BASE OF PALÆOZOIC ROCKS IN BRITAIN AND ELSEWHERE.—THE EOZOON.—GENERAL PALÆOZOIC SUCCESSION.

THE earliest condition of the earth is necessarily the least susceptible of investigation. The favourite hypothesis concerning the primary state of the planet, founded on astronomical and physical analogies, is, that it assumed the form of an oblate spheroid from rotation on its axis when in a fluid state. Reasoning upon this idea, and looking to the structure of those rocks which either lie at great depths or have been extruded from beneath, the geologist has inferred that the crystalline masses, including granites, which often protrude from below all other rocks, constituting possibly their existing substratum, were at one time in a molten state. The theory of an internal heat, at first sufficiently intense to maintain the whole terrestrial mass in a state of fusion, but subsequently so far dissipated by radiation into space as to allow the superficial portion to become solid, has been adopted by the greater number of philosophers who have grappled with the difficult problem of the primal state of our planet. Most of them likewise have believed that all the great outbursts of igneous matter, by which the crust has been penetrated and its surface in great measure diversified, were merely outward signs of the continued internal activity of the primordial heat, now much repressed by the accumulations of ages, and of which our present volcanos are feeble indications. If, then, the mathematician has correctly explained the causes of the shape of the globe, the geologist confirms his views when, examining into the nature of its oldest massive crystalline rocks, he sees in them clear proofs of the effects of great heat and pressure. The breaking up of the original crust of the

earth was, we may believe, marked by intruded masses issuing, at least partly, in a melted condition, and often constituting the axes and centres of former mountain-chains very different from those which now exist. Each great igneous eruption gave out substances which became, on cooling, solid rocks; and, when raised into the atmosphere with the associated metamorphosed strata, they constituted lands afterwards exposed to innumerable wasting agencies, thus affording materials to be spread out as fresh deposits upon the shores and bed of the ocean. In these hypothetical views concerning the production of ancient sediments formed under water, we seem to reach a primary source, and, once admitting that large superficial areas were originally occupied by igneous rocks, we have in them a basis from which the first sedimentary materials may have been obtained.

The earlier eruptions accompanied elevations at some points and collapses or depressions at others; these changes of outline, aided by the grinding action of waves, would occasion the formation of bands of sediment, which, adapting themselves to the inequalities of the surface, must have been of unequal dimensions in different parts of their range. In this way we may imagine how, by a repetition of the processes of elevation and denudation, the earliest exterior rugosities of the earth would be in some places increased, while in others they would be placed beyond the influence of sedimentary accumulation. We may also infer that the numerous molten masses of great dimensions which were evolved from the interior at subsequent periods must have made enormous additions to the earliest formed external crust of the earth, and have constituted grand sources for the augmentation of new deposits.

Turning from the igneous rocks to stratified deposits, we now know that vast masses of gneiss, micaceous schists, chloritic and quartzose rocks, clay-slates, and limestones, once called 'primary,' are really of subaqueous origin. Many of these, indeed, are nothing more than sediments of various epochs, which have been altered and crystallized long subsequent to their accumulation. This inference has been deduced from positive observation. A rock, for example, has been tracked from the districts where it is crystalline, to other spots where the mechanical and subaqueous origin of the beds is obvious, and from the latter to localities where the same stratum is wholly unchanged and contains organic remains. Transitions are thus seen from compact quartz-rock, in which the grains of silica are scarcely discoverable even with a lens, to strata in which the sandy, gritty, and pebbly particles bespeak clearly the original accumulation of the mass under water. Equivalent passages occur from crystalline, chloritic, and micaceous schists into those clay-slates which are little more than consolidated mud, and from crystalline marble to common earthy limestone, in which organic remains abound. This kind of metamorphosis comprehends such changes, for example, as those by which ordinary limestone has been converted into dolomite and sulphate of lime or gypsum,—also

shale into mica-schist, as seen in the Secondary and even in the Tertiary rocks of the Alps*.

Elementary works, indeed, will have informed the student that such mutations of the original sediment have been generally accounted for by the supposed influence of great heat proceeding from the interior of the earth, and which at different periods had manifested its power in the eruption of granite, syenite, porphyry, greenstone, basalt, and other substances formed by fusion. Let it, however, be understood, that the prodigious extent to which the metamorphism of the original strata has been carried in mountain-chains, and at various periods through all formations, though often probably connected with such igneous evolutions, must have resulted from a far mightier agency than that which was productive of the mere eruptions of molten matter or igneous rocks. Many of the latter are, in fact, but partial excrescences in the vast spread of the stratified crystalline rocks,—accompanying symptoms of the grander changes which resulted from deep-seated causes, probably from heat, electricity, and pressure, lateral as well as vertical, acting upon humid deposits with a powerful intensity.

Processes now going on in nature on a small scale, or imitated artificially by man, may enable us to comprehend imperfectly in what manner some of these infinitely grander ancient metamorphoses were effected; and experimental chemistry, when more extensively applied to the analysis of rocks, will, it is hoped, some day reveal still more important truths in this very obscure subject among ancient geological phenomena.

But speculations on such physical operations are not here called for†. The main design of this work is to mark the most ancient strata in which the proofs of sedimentary or aqueous action are still visible,—to note the geological position of those beds which in various countries offer the oldest ascertained signs of life, and to develope the succession of deposits that belong to such protozoic zones. In thus adhering to subjects capable of being investigated, it will be seen that Geology, modern as she is among the sciences, has revealed to us that, during periods immeasurably long anterior to the creation of the human race, and while the surface of the globe was passing from one condition to another, whole races of animals, the several groups being adapted to the physical conditions in which they lived, were successively created, lived their appointed time, and perished. It is to the first stages only, or Palæozoic, of these grand accumulations, and to the creatures entombed in them, that attention is now to be directed.

The convictions at which I have arrived being the result of many years of research, I have been induced to give a condensed, and, as far as prac-

* See my memoir on the Alps, Apennines, and Carpathians, Quart. Journ. Geol. Soc. vol. v. p. 157 et seq.

† The reader who desires to study the laws by which the superficial temperature of the earth has been regulated in the immensely long geological periods, will find them well explained in the profound essay of the late Mr. William Hopkins of Cambridge, "On the causes of changes of climate at different geological periods," Quart. Journ. Geol. Soc. Lond. vol. viii. p. 56.

ticable, a popular view of the oldest sedimentary rocks and of their chief organic remains, and thus to comprise in one octavo volume the essence of my own works *, as well as those of my associates, which have been published since the last edition of 'Siluria.'

But before any description of these ancient deposits, as now known, is given, a few words are required in explanation of those researches by which our acquaintance with the earliest vestiges of life and order in the protozoic world has been attained.

The first step which led to the present general palæozoic classification, as admitted by my cotemporaries, was the establishment of the Silurian System of rocks and their imbedded fossils. Before the labours which terminated in the publication of the work so named, no one had unravelled the detailed sequence and characteristic fossils of any strata of a higher antiquity than the Old Red Sandstone; and even that formation was known merely as the natural base of the Carboniferous or Mountain-Limestone, and as containing a few fossil fishes. Not only were the relations and fossil contents of all the lower strata undefined, but even many rocks which are now known to be younger than the Silurian were then considered to be of greater antiquity. No one had then surmised that certain hard slates with fossiliferous limestones and sandstones, which have since been termed Devonian, were equivalents of the Old Red Sandstone, and younger than, as well as distinct from, the deposits of the still older Silurian era. On the contrary, British authorities believed (and I was myself so taught) that the schistose and subcrystalline rocks of Devonshire and Cornwall (most of which are now proved to be of the date of the Old Red Sandstone) were about the most ancient of the vast unclassified heaps of greywackè. In short, the best geologists † of my early days were accustomed to look upon all such rocks as obscure sedimentary masses, in and below which no succession of "strata as identified by their fossils" could be detected. The result of research, however, has been the development of several well-defined formations, all of which, even including the Lower Carboniferous strata, were formerly merged, in Germany, in the purely lithological term 'grauwacké.'

Desirous of throwing light on this dark subject, I consulted my valued friend and instructor, the late Dr. Buckland, as to the region most likely to afford evidences of order, and by his advice I first explored, in 1831, the banks of the Wye between Hay and Builth. Discovering in that year a considerable tract, in Hereford, Radnor, and Shropshire, wherein large masses of grey-coloured strata rise out from beneath the Old Red Sandstone, and contain fossils differing from any which were known in the

* See 'Silurian System,' Murchison, 1839; and 'Russia in Europe and the Ural Mountains,' by Murchison, de Verneuil, and de Keyserling; J. Murray, London, 1845. Also numerous papers in the publications of the Geological Society of London from the year 1832 to 1864.

† See those classical works, the first Geological Map of England, by W. Smith (1815), the subsequent map of Mr. Greenough (1819), and the Geology of England and Wales, by the Rev. W. B. Conybeare and W. Phillips (1822).

upper deposits, I then began to classify these rocks. After four years of consecutive labour, during which I received much valuable assistance from the Rev. T. Lewis, of Aymestry, and Dr. Lloyd, of Ludlow, and exhibiting each year fossil evidences before the Geological Society to prove the independence and succession of the strata, I assigned to them (in 1835) the name "Silurian," deriving it from the portion of England and Wales in which the successive formations are clearly displayed, and wherein an ancient British people, the Silures, under their king Caradoc (Caractacus), had opposed a long and valorous resistance to the Romans. Having first, in the year 1833, separated these deposits into four formations*, and shown that each is characterized by peculiar organic remains, I next divided them (1834, 1835) into a lower and an upper group, an arrangement which I hoped would be found applicable to wide regions of the earth. After seven years of labour in field and closet, the proofs of the truth of those views were more fully published in the large work entitled the 'Silurian System' (1838–9). As the original quarto has long been out of print, let me put the reader in possession of some of the leading views it contains, by quoting the following passages, in which, having previously described the overlying deposits, the lowest of which is the Old Red Sandstone (since termed Devonian), I thus ushered in the new classification:—

"We have at length reached those older deposits, which, not having been separated into formations by previous writers, I am compelled to describe under new terms.

"Acting upon the principle that guided William Smith in subdividing the Oolitic system of our island, I have named these rocks from places in England and Wales where their succession and age are best proved by order of superposition and imbedded organic remains, and have termed them in descending order, the 'Ludlow,' 'Wenlock,' 'Caradoc,' and 'Llandeilo' formations. The same principle has led me to use the general term of 'Silurian System' for the group, to mark thereby the territory in which the best types and the clearest relations are exhibited.

"Like every other mass of strata entitled to the name of System, the Silurian, though clearly recognizable as a whole over extensive tracts, cannot always be subdivided into those formations which are displayed in the regions where I shall first describe it, and where its types are fully developed. Thus, for example, where the subordinate limestones thin out and disappear, the Ludlow deposit can seldom be clearly separated from that of Wenlock. In such cases both these formations are included in the term of 'Upper Silurian Rocks,' and, under similar cir-

* For the first tabular view of these four formations, the lower one resting on the then so-called 'unfossiliferous greywacke' (afterwards named 'Cambrian') of the Longmynd, see Proceedings Geol. Soc. Lond. vol. ii. p. 11, Jan. 1834. The chief characteristic fossil species were even then enumerated, and specimens placed in the Museum of the Geological Society; and hence the classification which is now sustained is essentially thirty-two years old. It had even been previously stated by me (in 1833) that the lowest fossil-bearing formation then known to me, or the 'black trilobite flagstone' of Llandeilo, probably exceeded in thickness any of the superior groups (Proc. Geol. Soc. vol. i. p. 476).

cumstances, the Caradoc sandstones and Llandeilo flags in that of 'Lower Silurian Rocks.'

"Simple as this classification may now appear, those versed in practical geology can well understand what must have been the amount of examination employed in its perfect establishment. To comprehend the extent of the break in the history of the older strata which has been filled up by the study and classification of these rocks, the student has only to refer to the tabular view I have prepared, and compare it with other tables framed upon an antecedent state of geological knowledge. He will then perceive, that what is here presented to him as a well-ordered succession of great thickness (each subdivision of rocks being characterized by a corresponding suite of organic remains*), was formerly considered one assemblage, without definite sequence, and included under the unmeaning names of 'greywackè' or 'transition limestone.' I have already explained that the latter term has been as liberally bestowed (chiefly, however, by foreigners) upon the Carboniferous limestone, from which the Silurian rocks are separated by that enormous accumulation, the Old Red Sandstone; whilst the organic remains of both these systems are entirely dissimilar from those of the carboniferous era......Let us now proceed to consider these Silurian deposits in the natural order in which they appear in the south-west of Salop and adjacent parts of Herefordshire."

During my early researches (1833), it was shown that the lowest of these fossil-bearing strata then known to me, including the Llandeilo flags, and their natural base the Stiper Stones, reposed, in the west of Shropshire, on a very thick accumulation of still older sediment, constituting the Longmynd Mountain; and the strata of the latter, not then offering a vestige of former life, were at first termed 'unfossiliferous greywackè'†.

As in examining all the strata of England and Wales from south-east to north-west it had been found that there was a regular succession from younger to older rocks, so at the time when I propounded the Silurian classification (1835) it was the belief of all geologists who had examined the country‡, that the slaty rocks of North Wales rose up from beneath my Silurian types of Shropshire and the counties of Montgomery, Hereford, and Radnor. In this belief I coincided, without surveying the north-western tracts of Wales. Hence another term, or that of

* These organic remains were laid before the Geological Society, and named, in each succeeding Session from 1831 to 1838, when the large work, the 'Silurian System,' was completed and published.

† The Stiper Stones were classed by me in 1833 and 1831 as the base of the overlying series, which was termed Silurian as early as 1835. See Phil. Mag. vol. vii. p. 46, with a diagram showing such Silurian rocks reposing on 'unfossiliferous greywackè.' The Government Geological Surveyors have designated as 'Cambrian' only those rocks of Wales which, like my original type the Longmynd, underlie all the strata with Silurian fossils.

‡ See all the early geological maps, and even the last edition of the Map of Greenough (1839). In 1838 also, Professor John Phillips still held this belief, as well as myself and others, and gave in the Penny Cyclopædia (art. GEOLOGY) a section across Britain, in which the Snowdon and North-Welsh rocks are placed below the Caradoc and Llandeilo formations

'Cambrian,' which Professor Sedgwick proposed, and which I applied to the Longmynd of Shropshire, was in the year 1836, or a year after the introduction of the name 'Silurian,' also applied to the rocks of North Wales. All these rocks were supposed by myself and other geologists, including Professor Sedgwick, to be of older date than the Silurian, before their true relations, physical and zoological, to the then recognized Silurian strata of Shropshire had been ascertained. The assumed inferior position of the slaty rocks of North Wales being considered a fixed point, it was naturally thought that such formations, the fossils of which were then undescribed, would be found to contain a set of organic remains differing, as a whole, from those of the classified and published Silurian system. With others, therefore, I waited for the production of the fossils which might typify such supposed older sediments; for in obtaining the knowledge I had then acquired, by working down from upper strata whose contents were known, to lower and previously unknown rocks, I had invariably found that the inferior masses were characterized by distinct organisms. This principle, which had been established in the Tertiary and Secondary deposits, was thus proved to be universally applicable, by the occurrence of similar distinctions in the Carboniferous, Old Red, and Silurian rocks.

It was, however, in vain that we looked to the production of a peculiar type of life from the North-Welsh slaty rocks. Professor Sedgwick's collections derived from that region had long remained unexamined; but as soon as he called palæontologists to their inspection, Silurian fossils, already named in my works, were alone found in them; and the reason has since become manifest. The labours of many competent observers during the succeeding years proved that the great mass of these slaty rocks are not inferior in position, as once supposed, to the Lower Silurian strata of Shropshire and the adjacent parts of Montgomeryshire, but are merely extensive undulations of the same; and hence the looked-for geological and zoological distinctions could never have been realized. Sharpe, De la Beche, Ramsay, E. Forbes, Selwyn, Salter, and other explorers have demonstrated that the chief fossil-bearing rocks of North Wales are, both in order and contents, the absolute equivalents of the strata in Shropshire and Montgomeryshire long previously described and named by me 'Lower Silurian.' They therefore used the Silurian nomenclature in all their works and maps relating to North Wales*.

But although in 1838, when my large work was really completed†, I still held, in common with my associates, the erroneous idea of the infra-Silurian position of the slaty rocks of North Wales, I soon saw reason to

* See also Phillips on the Malvern and Abberley Hills; Memoirs Geol. Surv. vol. ii. pt. 1, 1848. The student who wishes to obtain a complete acquaintance with the rock-structure of North Wales should consult the 3rd volume of the Memoirs of the Geological Survey of Great Britain, by A. C. Ramsay, F.R.S., with Map and Sections, and with a copious Appendix illustrating the Fossils of that region, by J. W. Salter, F.G.S.

† Although 1839 is on the title-page, extracts from published copies of the work were quoted by authors in 1838 (see Lyell's 'Elements of Geology' of that year).

abandon that view, and to adopt the opinion which I have maintained for a quarter of a century. I ascertained, in short, that in Bohemia, Scandinavia, and Russia, the rich inferior zone of primeval life was the same Lower Silurian as in Britain and America. Indeed I made a transverse section in 1842, accompanied by my coadjutor A. von Keyserling, north-westward from Shropshire, and was convinced that all the undulating fossiliferous rocks of North Wales were mere extensions of Silurian types. During the same year the Government Geological Surveyors had arrived at similar results through their own labours in South Wales. In that country, Professor Ramsay first discovered (1842) that, to the north and west of my typical position of Llandeilo, true Silurian rocks, characterized by their fossils, folded over, and occupied a wide region, which, in 1836, and without examination, I had mapped as Cambrian (simply because it lay to the north-west). Thenceforward Sir H. De la Beche and the Surveyors naturally coloured as Silurian all such hitherto undefined tracts *.

My view of the equivalents of the Silurian rocks in North Wales, Russia, and Scandinavia, published in the year 1842†, was adopted generally in Europe and America, through independent comparisons by numerous foreign geologists of their older formations with my British types.

In extending researches to various distant lands, I found that as the base of all rocks containing Silurian fossils, in Bohemia, Scandinavia, and Russia, was clearly defined, and as the same fact was announced from North America, it was no longer difficult to describe the whole organic series, and thus to record the succession of crustaceans, mollusks, and other invertebrata from their earliest distinguishable types. In a word, as chroniclers of lost races, de Verneuil, von Keyserling, and myself were enabled to register, in our 'Russia and the Ural Mountains'‡, the relative position of such ancient creatures. To the first chapters of that work, as explanatory of views which are here reiterated, the reader is referred. Then it was that positive proofs, derived from a wide field of observation, enabled us to commence the geological history of a region occupying half the area of Europe, with an account of the entombment of the earliest animals recognizable in that vast region, and also to indicate the successive conditions which prevailed upon the surface, in a long series of ages, and during the many changes of outline which long preceded the present state of the planet. Looking to all the records of former life, as exhibited in the strata, it was then demonstrated, from phenomena in one great empire alone (as had to a great extent been shown in Britain), that, during the formation of the sediments which compose the crust of the earth, the animal kingdom had been at least three times entirely renovated, the Secondary and Tertiary periods having each been as clearly characterized by a distinct fauna as the Primeval. In the work on Russia, the

* See Ramsay's 'Geology of North Wales,' Memoirs of the Geological Survey, vol. iii. p. 6.

† Discourse of the President of the Geological Society of London, 1842; Proceedings Geol. Soc. Lond. vol. iii. p. 640 &c.

‡ The general views were communicated in 1842 The large work was published in 1845.

Ural Mountains, and Scandinavia, the sequence was thus followed out, from the most ancient fossil-bearing strata of those regions to the latest stages in the geological series.

The leading object, therefore, of the present work is not, I repeat, to bring out the 'Silurian System' in a mere abridgment of its original form, but to concisely describe the Silurian system of rocks, such as that system became in subsequent years, before it obtained the highest distinction which the Royal Society bestows*, and what it long since proved to be, with the additions made to it by other geologists at home and abroad.

In the present volume attention is chiefly restricted to the consideration of the earliest great eras of life. The plan, therefore, pursued will be, so far, similar to that which was adopted in the large work on Russia; and these leaves of geological history will be written from the first traces we have obtained of organic remains,—a plan which, for want of knowledge, was impracticable when the 'Silurian System' was issued in 1838.

After 1854, when the first edition of the present work was published, and even after many pages of the second edition were printed, a most important addition was made to our acquaintance with the lowest or fundamental rocks of America and Europe, to which it is necessary at once to allude.

The Laurentian or Oldest known Stratified Rocks.—In the last edition of this work it was shown, and even represented in the coloured frontispiece, which is now repeated, that the classification previously adopted by British geologists, and which assumed that the Cambrian rocks, or their altered equivalents, were the oldest deposits in our islands, had been set aside by evidence proving the existence of stratified rocks beneath all those to which the terms of Cambrian and Silurian had been applied.

My scientific cotemporaries are aware that I was the first to announce the existence of Laurentian rocks in Britain, as proved by a true order of their infraposition to Cambrian and Lower Silurian rocks, which I observed on the north-western coast of Scotland. This view was communicated to the Geological Society of London, and accompanied by a new geological map of the Highlands, on which the Laurentian gneiss was clearly separated from the younger gneissic and crystalline rocks occupying so large a portion of that region (see Quart. Journ. Geol. Soc. Lond. 1848–49). For, although MacCulloch and others had shown that the gneiss forming the lower headlands of the west coast of Sutherland was unconformably surmounted by red sandstone and conglomerate, they did not possess at that time the means of testing the relative ages of the various rock-formations. In those days the Silurian classification was unknown, no organic remains had been discovered in the limestones of Sutherland; and Professor Sedgwick and myself had simply observed, in the year 1827, that the limestones which have since proved by their imbedded fossils to be of Lower Silurian age passed conformably under micaceous schists and quasi-gneissic

* The Copley Medal (1849).

and chloritic crystalline rocks. In the absence of any fossils, provided with no classification (for some years elapsed before we entered into the study of the Silurian and Cambrian rocks), we necessarily failed to clear up the order, and remained in the belief of our precursors, that the sandstones and conglomerates forming the chief mountains on the west coast, and resting upon buttresses of old gneiss, were simply the equivalents of the well-known Old Red Sandstone of Scotland.

This erroneous opinion continued to be upheld for many years, and was widely circulated in the justly popular and able work, 'The Old Red Sandstone,' of the lamented Hugh Miller. The error was first removed by a survey of the western coast of the Highlands, which I made in 1854, and in which, at my request, Professor Nicol became my companion; for I had long wished to ascertain the rationale of the singular succession I had seen many years before, and wished to search out carefully the whole order of those rocks. Some of the results were communicated to the Meeting of the British Association at Glasgow. In the subsequent year (1855) Professor Nicol added considerably to the value of the first survey; and by his labours, combined with my own in a subsequent year, it was made manifest that the so-called 'Old Red Sandstone' of the north-western coast was a rock of much higher antiquity than that which overlies the Silurian System; for these sandstones and conglomerates of the west were seen to be overlain unconformably by those very quartzites and limestones which Sedgwick and myself had observed to pass with a south-easterly dip under crystalline rocks constituting the great mass of the gneissic schists and micaceous flagstones of the central and eastern Highlands.

The question then arose, What is the age of those quartzites and limestones which have a much less crystalline character than the rocks by which they are overlain? In the quartzites MacCulloch had, it is true, discovered minute organisms, which he classed with Orthoceratites, and which are now known to be the infilled borings of Annelids and small Crustacea. It was not, however, until Mr. Charles Peach discovered, in the limestones of Durness, clear and unmistakeable fossils of various sorts, which in the hands of Mr. Salter proved to be the Lower Silurian fossils to be noted hereafter, that I became possessed of the key which I had long sought for, and by which I was at once enabled to develope the whole order of the North-Scottish succession, from a Fundamental Gneiss upwards, through Cambrian and Lower Silurian rocks, to the Old Red Sandstone.

Seeing that the fossiliferous limetones of Sutherland were by no means the oldest of the Silurian deposits of my classification (being of younger age than the whole series of the Lingula-flags or "Primordial [Silurian] Zone" of Barrande), and that they reposed transgressively upon different members of the next underlying formation, or the red and purple hard

grits and conglomerates that compose the loftiest mountains in the West Highlands, it followed that these rocks must unquestionably represent, at least in great part, the Longmynd or true Cambrian rocks of South Britain and Wales. Now these hard grits and conglomerates are seen to repose abruptly on highly inclined and contorted strata of massive hornblendic gneiss which, unlike the overlying Cambrian and Lower Silurian strata, has a direction or strike nearly at right angles to them,—the former trending from N.W. to S.E., the latter from N.E. to S.W. The fact of the great divergence of strike, which I laid down on my geological map of the Highlands*, being coupled with the clearest evidences of infraposition to Cambrian and Silurian rocks, I had no longer any doubt that these rocks were of a remoter age than any which had been previously recognized in the British Isles. Hence I at first termed them 'Fundamental Gneiss,' and soon after, following my distinguished friend Sir W. Logan, I applied to them his term 'Laurentian,' and thus clearly distinguished them from the younger gneissic and micaceous crystalline rocks of the Central and Eastern Highlands†, which were classed as metamorphosed Lower Silurian. I was, indeed, fortified in adopting this classification by my associate Professor Ramsay, who accompanied me in 1859 to the Northern Highlands, and who not only assented to my views, but who, having himself recently returned from Canada, assured me that the Scottish base was unquestionably the same as that of North America.

In the recently published and highly instructive Geological Map showing the distribution of the Laurentian Rocks in Northern Canada, Sir W. Logan and his associates ‡ have exhibited in separate colours no less than seven divisions of the Lower Laurentian, including four separate stages of orthoclase-gneiss and three of interstratified limestones. The Upper Laurentian or Labrador group consists mainly of anorthosite-gneiss. These rocks, with some syenite and porphyry and an occasional dyke of greenstone, occupy the whole region.

Let us now endeavour to determine whether these Laurentian rocks of the Western Highlands of Scotland, which are manifestly the foundation stone of all the formations in the British Isles, pertain to the Lower or the Upper division of the North-American Laurentian System of Logan. If we

* This great change in the estimate of the relations and succession of the rocks in the North of Scotland was fully explained in memoirs communicated to the Geological Society (Quart. Journ. Geol. Soc. vols. xv. and xvi.), and illustrated by a geological map of the Highlands, on which the new classification was for the first time represented.

† Professor Nicol differs from me in this separation of the older from the younger gneiss, and, considering them both to be parts of the same series, he follows the old classification of MacCulloch. He believes that the gneiss which forms the low headlands of Sutherland and Ross (my fundamental or Laurentian rock) is brought up to the east of the fossiliferous Silurian limestones and quartz-rocks by great faults and curvatures. From that opinion of my former associate I entirely dissent; and my view is sustained by every other geologist who has explored the country, including Professors Ramsay and Harkness, Colonel Sir H. James and Mr. Archibald Geikie. Resolving to look closely into the objections raised by Professor Nicol, I induced Mr. Geikie to accompany me through the north-western Highlands in 1862; and as he, after much labour, confirmed all my conclusions, we thereupon published the Geological Map of Scotland, which has been largely sold by Mr. A. Keith Johnstone.

‡ The Canadian Geological Survey consists of Sir W. Logan, as Director, with his assistant Mr. A. Murray, Dr. T. Sterry Hunt, Chemist and Mineralogist, and Mr. E. Billings Palæontologist. They have been ably supported by Dr. Dawson, the Principal of M'Gill College, Montreal.

look to the lithological structure of the Scottish rock, we cannot discover any close relationship between it and the Upper Laurentian rock of Canada, or 'Labrador Series;' for this last is essentially composed of felspars, often rich in alkalies, especially soda, and is thereby markedly distinguished from the British formation, which, throughout its range, from Cape Wrath to Lochs Broom, Torridon, and Maree, as also in the island of the Lewis, is a granitoid, massive gneiss, in which hornblende and quartz predominate very largely over felspar and mica. Like the grand Lower Laurentian of Canada, it contains limestone; but instead of the thick development of calcareous matter of the American deposit, the limestone layers in it are thin, fissile, and of very rare occurrence. Hence we might well have expected that if any traces of organic bodies were to be detected in rocks of this age, previously termed 'Azoic,' they would be found in those extensive and thick masses of limestone which occur in the Lower Laurentian of America. Thus, whilst it is in them that the Rhizopod named Eozoon Canadense by Principal Dawson* has been detected, our chances of discovering this little fossil in our attenuated and scaly British limestone are slight indeed. Yet this same zoophyte, which, like the polyps of succeeding epochs, and of our own day, formed ledges or layers incrusting the most ancient known rocks, has been recently detected, by MM. Gümbel, Fritsch, Hochstetter, and Reuss, in the limestone of the older gneiss of Bohemia and Bavaria. I may here be excused for stating that, in 1862, when I explored for the last time the mountains of Bohemia, I placed that same gneiss, of which there are two sorts, on the parallel of the Laurentian of America and Scotland. For I felt assured, by the infraposition of the rocks in both countries to the other recognized palæozoic groups, that their age must be pre-Cambrian. For example, when I saw in Bohemia and Bavaria enormous masses of clay-slate, mica-schist, &c. lying beneath Barrande's 'Zone Primordiale,'—masses which obviously occupied the place of the 'Cambrian' of the British Geological Survey, and reposed upon primordial gneiss, I could draw but one inference; and hence I affirmed that these rocks of Central Germany were of Laurentian age,—and this before they were so styled by any other author, and long before an Eozoon was found in them†.

Further, I have recently learned from Dr. Geinitz that the Eozoon has been also discovered in the crystalline limestone of Maxen, in Saxony, south of Dresden. Thus we now know that in the heart of Europe, as in America and Britain, there exists a nucleus of the oldest traceable stratified rock, around and over which the succeeding Palæozoic formations have been accumulated.

There is also little doubt that in the northern and central parts of Nor-

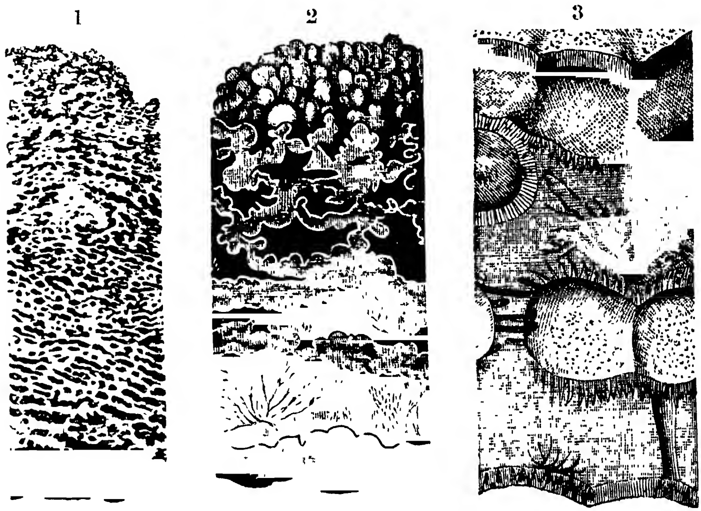
* Quart. Journ. Geol. Soc. vol. xxi. p. 54; vol. xxii. p. 609, &c. Canadian Naturalist and Geologist, April, 1865. Intellectual Observer, No. 40. Popular Science Review, No. 15, &c.

† See my memoir on the Gneiss and superjacent Palæozoic Formations in Bavaria and Bohemia, Quart. Journ. Geol. Soc. vol. xix. p. 359.

way the same foundation-stones exist, and have their proper place far beneath the well-known Silurian formations of Sweden and Norway.

The figures of Eozoon Canadense, which are here given, have been selected by my friend Professor Rupert Jones from the works of Principal Dawson and Dr. Carpenter.

FOSSILS (1).



1. Portion of the serpentinous marble of Canada, composed of Eozoon; of the natural size. The broken black lines represent the serpentine, and the white spaces are the calcareous skeleton. Copied from Dr. Dawson's nature-printed section of a specimen of Eozoon Canadense (from Petite Nation Seigniory), first polished and then corroded with acid. [See Canadian Naturalist and Geologist, April, 1865.]

2. The serpentinous portion of a piece of Eozoon, after maceration in acid, magnified. It presents the natural casts of the chambers and tubes, or a model of the sarcode of the Eozoon. (After Dr. Carpenter's plate in the Intellectual Observer, No. XL. p. 300 &c.)

3. A portion of the chamber-walls, or calcareous shell, of the Eozoon, restored and highly magnified, showing the tubuliferous walls, the pseudopodial tufts in the intermediate skeleton, and the stolon-passages. (After Carpenter. *loc. cit.*)

As these authors, who have long studied this class of animals, are supported by Reuss and other sound foreign naturalists in their belief that the Eozoon (of which two nominal species have been described) is truly a Foraminifer, I bow to their decision, and regard the Laurentian as the base of all Palæozoic deposits.

Whilst the Laurentian gneiss of Scotland differs essentially (as I have shown in other publications*) from the superjacent crystalline rocks (gneiss in parts) of Lower Silurian age, the most marked distinction, besides its infraposition, consists in the entire divergence of its direction or strike, and its abrupt separation from all the overlying formations. Thus, whilst

* For many complete demonstrations of the infraposition, in the Western Highlands and the Hebrides, of the Laurentian gneiss to the Cambrian sandstones and conglomerates, and of the latter to Silurian rocks (the latter being often highly crystalline, gneissose, and micaceous), see the memoir by Mr. Geikie and myself, Quart. Journ. Geol. Soc. May 1861 vol. xvii. p. 171 &c. See Chap. VIII.

the Cambrian and Lower Silurian rocks of the Highlands range, as before said, from N.E. to S.W., the Laurentian, lying beneath them, has a strike from N.W. to S.E., and is utterly discordant to them, as laid down in the maps of Scotland before spoken of. Considering this great break, and seeing that the sandstones and conglomerates which next succeeded were derived from the subjacent gneiss after it had passed into a crystalline condition, we are lost in the endeavour to form an estimate of the incalculable length of time which must have elapsed between the first accumulation of the Laurentian deposit and its crystallization, and, after that change, to account for the great hiatus which separates that rock from the younger deposits made out of its fragments. How vast must have been the contortion, dislocation, metamorphism, and denudation which intervened in that period, concerning which many leaves in the geological register are wanting! In reviewing the natural features of the stratified succession in the Western Highlands, I am therefore led to believe that the lowest gneiss of that region is the representative of the Lower Laurentian of Canada—the oldest sedimentary deposit as yet known in the crust of the globe.

In the succeeding Cambrian rocks, traces of animals superior in grade to the Eozoon will presently be described; and those rocks I still consider to be the basement-strata of all the deposits of England and Wales. For, notwithstanding the ingenious and able sketch of Dr. Holl *, who has inferred that the crystalline nucleus of the Malvern Hills is of Laurentian age, I cannot subscribe to his view, whether I look to the composition and direction of these rocks, or to the geological sequence which is there exposed. The fine-grained, fissile, and foliated Malvern rocks, in which felspar and mica abound, do not at all resemble the hard, thick-bedded, massive, older gneiss of the Highlands, except in the presence of some hornblende. Then, again, these Malvern rocks are parallel to the flanking Silurian deposits—thus differing in the most marked manner from the discordant relations of the Highland rocks, but agreeing exactly with the parallelism of the Cambrian to the Silurian rocks in Shropshire, Wales, and Scotland. Again, among the miniature series of stratified deposits which overlie the crystalline nucleus of the Malverns, there exists no representative whatever of those enormously thick deposits of the Longmynd, or Cambrian of the Geological Survey. The observer proceeds at once from crystalline rocks to the Holybush Sandstone, which was long ago shown to be the base of the Silurian deposits of the tract, by Professor Phillips and myself. My inference therefore is, that the crystalline schists and gneissic rocks of the Malverns represent the older portion of the Longmynd or Cambrian rocks, and that they stand in the place of similar rocks in Carnarvon and Anglesey, which are simply the metamorphosed Cambrian rocks of the adjacent parts of North Wales †.

* Quart. Journ. Geol. Soc. vol. xxi. p. 72 &c.

† For these conversions of Cambrian strata into crystalline rocks, see Ramsay's 'Geology of North Wales,' Memoirs of the Geological Survey, vol. iii. pp. 164, 166, 167, 169, 177. See a fuller sketch of the Malvern Hills in Chap. V.

Reverting now to the Silurian region proper, in which those researches began which enabled me to prepare the 'Silurian System,' I take leave of the Laurentian rocks with the expression of my belief that they have no existence in England and Wales, nor, as far as I know, in Ireland*.

The most zealous researches of collectors and palæontologists during the last quarter of a century, though pertinaciously directed to this point, have failed in detecting any other traces of former life in the Cambrian rocks than the few relics which will presently be described—albeit in a large portion of their range the Cambrian strata of the Longmynd, having an estimated thickness of 26,000 feet, are very slightly altered. No sooner, however, do we examine the deposits formed subsequently than we meet thenceforward with a never-failing storehouse of organic remains.

In the lithograph given in the Frontispiece, repeated from the former edition, there is an attempt to represent, by colour and indications of stratification, the succession of the most ancient rocks as seen in looking westward from Inchnadamff on Loch Assynt in Sutherland. Thus the low distant hills forming the sea-coast consist of that fundamental or Laurentian gneiss (*a*) which is older than any rock in England and Wales. Next, the lofty mountain of Queenaig, composed of horizontal, chocolate-coloured, hard sandstone and conglomerate (*b*), is of the same age as the Cambrian rocks of the Longmynd in Shropshire, and Harlech in Wales, which, as will presently be shown, lie beneath the whole of the Silurian strata of Wales and England. The overlying sloping masses descending into the foreground are quartzites or altered sandstones (c^1 and c^3), with included crystalline limestones (c^2); and these (when they range into Durness) contain about twenty species of Lower Silurian fossils†.

After a short sketch of the earliest or Cambrian zone of sediments of the Silurian region, full descriptions will be given of the Lower and Upper Silurian rocks. Other chapters will treat of the strata (now termed Llandovery rocks) which unite the two groups, and of the upper members of this great natural series. Whilst so separated for purposes of classification, it will, however, be clearly shown that, through their organic remains, these deposits comprehend but *one great system of life*. Condensed accounts will then follow of the overlying or

* Inasmuch as the Eozoon Canadense frequently occurs in serpentinous limestone, it was at one time supposed that it had been discovered in the green marble of the Connemara Mountains in Ireland. In a future page it will be shown that this Irish rock is of Lower Silurian age. Now, without entering into the controversy respecting the true character of the Eozoon, I may state that much ability was displayed by Dr. Rowney and Professor W. King, of Galway, in their recent effort to show that the forms of Eozoon which they examined were purely referable to chemical and mineral conditions. On this point I will only say that, believing, as I do, the Eozoon to be a Foraminifer, I can see no valid objection to the adoption of the belief that a marine creature of that class may have lived on from the Laurentian to the Silurian era. Thus some of the Foraminifera represented by siliceous casts in the Lower Silurian green sand of Russia (as will be noticed in the sequel) are probably identical with existing species; and Nodosarinæ undistinguishable from living forms are found in the Permian limestones. Many others also have lived on from the Secondary periods; and the same Globigerina that constitutes great masses of the Chalk now coats the bed of the Atlantic and other oceans.

† These fossils, discovered by Mr. C. Peach, are described in the Ninth Chapter.

younger palæozoic groups, termed Devonian, Carboniferous, and Permian. The Devonian is simply an intermediate zone between the great Silurian and Carboniferous systems, while to the last are closely linked on the Permian deposits. The Devonian rocks were in previous years known only as the Old Red Sandstone, a name which has become classical through the writings of Hugh Miller. These were termed Devonian, because the strata of that age in Devonshire, though lithologically unlike the Old Red Sandstone of Scotland, Hereford, and the South-Welsh counties, contain a much more copious fossil fauna, and were shown to occupy the same intermediate position as the Old Red Sandstone, between the Silurian and Carboniferous rocks. At that time, however, none of the fossil fishes of the Scottish or English Old Red had been found in the slates, schists, sandstones, or limestones of Devonshire, or of the Rhine; and objections might therefore have been raised to the term 'Devonian' as applied to the Old Red deposits. But the discovery made in Russia* of the same species of Scottish ichthyolites being there commingled in the same rock with forms of mollusca found in Devonshire †—similar tests being afterwards extended to Belgium and the Rhenish Provinces—firmly established the truth of the comparison. It was also shown by myself that the uppermost Silurian rocks of Norway (Christiania) are surmounted by copious masses of Old Red Sandstone ‡.

The Carboniferous rocks, so largely and fully developed in the British Isles, have been well investigated by many writers, particularly by Professor Phillips; and they have been found to extend, like the Silurian and Devonian, over immense regions in all quarters of the globe.

The great primeval or Palæozoic series is now known to terminate upwards, in Europe, with certain deposits for which, in the year 1841, I suggested the name of 'Permian.' In the earlier days of geological science in England, this group was classed with the New Red Sandstone, of which it was supposed to form the base; but extended researches have shown, from the character of its imbedded remains, that it is naturally united with the Carboniferous deposit below it, and is entirely distinct from the Trias, or New Red Sandstone, which, overlying it, forms the base of all the Secondary rocks. The chief calcareous member of this Permian group was termed in Germany the 'Zechstein,' in England the 'Magnesian Limestone;' but as magnesian limestones have been produced at many different periods, and as the German 'Zechstein' is a part only of a group, the other members of which are known as 'Kupfer-Schiefer' (copper-slate), 'Roth-todt-liegendes' (the 'Lower New Red' of English geologists), &c., it was manifest that a single name for the whole was

* See Russia in Europe and the Ural Mountains, vol. i. p. 64.

† Even in the rocks of South Devon Prof. Phillips and Mr. Pengelly have found a few fish-scales such as abound in the Old Red Sandstone ('Geologist,' vol. v. p. 458, &c.).

‡ Russia in Europe and the Ural Mountains, vol. i. p. 13; and Quart. Journ. Geol. Soc. vol. i. p. 469, and vol. viii. p. 182.

much needed. After showing how these variously named strata constitute one natural group in Germany as in other countries, I proposed to my fellow-labourers, de Verneuil and von Keyserling, that the vast Russian territory of Perm should furnish the required name *. The general adoption of the term 'Permian' is, indeed, the best proof of its usefulness.

In the opening chapter of 'Russia in Europe and the Ural Mountains,' a general view of this palæozoic classification was given as applied to Germany, France, Belgium, and North America; and in all of these countries, as well as in Russia, it was shown that a similar ascending order prevailed, from a base-line of recognizable Silurian life, through Devonian and Carboniferous deposits. In the twenty-one years which have elapsed since the issue of that work, considerable additions have been made to our knowledge; and all of them sustain the truth of the generalization. We then scarcely knew of the existence of true Silurian deposits in Germany, nearly all the 'grauwacké' of the Rhenish Provinces and the Harz having been assigned to the Devonian series; but since the opening out of the rich Silurian basin of Bohemia, which, in the skilful hands of M. Barrande, has become the palæozoic centre of the continent, Thuringia and Saxony have been also found to contain Silurian rocks.

In Spain, several mountain-chains have been shown by M. de Verneuil and the late M. Casiano de Prado to consist of Silurian followed by Devonian and Carboniferous rocks; whilst Mr. D. Sharpe has described the first and last of these groups as found in Portugal. Again, Sardinia, under the scrutiny of General A. della Marmora, has exhibited its Silurian and superjacent Coal deposits; and Devonian and Carboniferous strata overlie older rocks in North and, partially, in South Africa †.

In Siberia, the chief mineral features of which are described by Humboldt and Rose, my colleagues and myself have explained how the Silurian rocks of the Ural chain are succeeded by younger palæozoic deposits. M. Pierre de Tchihatchef has indicated a great extension of similar formations over large tracts of Southern Siberia, in the Altai Mountains, and Asia Minor; whilst to the north-east, since Adolf Erman traced such rocks even to the Sea of Ochotsk, able Russian authorities, particularly Schmidt, Radde, and others, have mapped and described palæozoic rocks in the vast countries around the Lake Baikal and extending from the region of the Amur to Mandchuria.

In the giant Himalaya, where, a few years since, no systematic labours had been devoted to the older strata, we now know that Silurian rocks, covered by Secondary or Mesozoic deposits, exist in those the highest

* See my letter to Dr. Fischer, Moscow, Oct. 1841, printed in Leonhard's N. Jahrb., and in Phil. Mag. vol. xix. p. 419.

† For North Africa, see Coquand, Bull. de la Soc. Géol. de France, 2 série, vol. iv. p. 1188. Some of the fossils collected by the lamented traveller Overweg, in his journey southwards, are also Devonian. For South Africa, the reader may consult a Memoir by Mr. Bain, published in the Trans. Geol. Soc. Lond. vol. vii. 1856. According to my distinguished friend Dr. Livingstone, the only European who has traversed and retraversed South Africa, coming out in the west at St. Paul di Laonda (lat. 10°), and at Quilimane on the east, there are strong beds of coal and ironstone on the banks of the Zambesi, and to the north-west of the Portuguese settlement of Tete.

mountains of the world, and that the Upper Punjaub of Hindostan contains a limestone charged with well-known Carboniferous fossils, reposing, as in England, upon a red sandstone *. It is also certain that the mountain-chains of China are composed, to a great extent, of these older rocks; for M. C. Skatschkof, Director of the Russian Observatory at Pekin, when preparing an account of the rich coal-fields (partially described by his countryman Kovanko) near that city, recognized, in the Jermyn Street Museum, certain Silurian Graptolites and Orthoceratites, Devonian Spirifers, and Carboniferous Producti as all being forms which he had seen in the rocks around the Chinese metropolis. Again, Devonian fossils of the very same species as those of England and the Continent have been given to me by Mr. W. Lockhart †, some from the interior province of Szechuan, and others from Kwangsi. Other fossils, identified by de Koninck as Devonian forms, were brought by M. Itier from the Yuennan province, one hundred leagues north of Canton ‡.

In Australia, where, not long since, reference could be made only to rocks of the Carboniferous and Devonian age §, we hear of many Silurian fossils, both in New South Wales and in Victoria ‖, like those of the British Isles ¶. In Victoria, indeed, numerous species of Lower Silurian fossils have already been recognized by Mr. Selwyn and Professor M'Coy in those slaty rocks which bear the chief auriferous quartz-veins.

In South America, the lofty Cordilleras and plateaux, whose mineral characters have been so admirably described by Humboldt, were shown by Alcide d'Orbigny to consist in great part of such ancient sediments; and more recently Mr. David Forbes ** described in considerable detail the true succession of these rocks, and brought home many characteristic Silurian fossils. Still more clearly has North America been found to contain a vast succession of these palæozoic rocks, and especially of their lower members. Numerous geologists of the United States have demonstrated that their ancient strata followed the same order on a very grand scale, and, in the western region, uninterruptedly,—doubtless due to their having been exempted in those tracts from the intrusion of igneous rocks. Spread out in enormous sheets over the southern districts of Upper Canada, the strata paral-

* The Himalayan data are given by Col. R. Strachey; those of the Upper Punjaub, by Dr. A. Fleming (Quart. Journ. Geol. Soc. vol. vii. p. 292, and vol. ix. p. 189) and by Mr. Theobald (Journ. Bengal Asiatic Society, 1854, p. 651 &c.). See also an account of Carboniferous rocks and fossils discovered by Capt. Godwin-Austen in Thibet and Kashmere, Quart. Journ. Geol. Soc. vol. xxii. p. 29 &c.

† See Proceedings of Roy. Geographical Soc., President's Address, 1858, vol. ii. p. 306.

‡ See a description of the Chinese coal-field near Pekin, by Kovanko, Ann. des Mines de Russie, An. 1838, p. 191. No geologist can peruse Mr. Fortune's lively description of the Bohea Mountains without supposing that a fine primeval succession may there be found. For the Chinese Devonian fossils, see Davidson, Quart. Journ. Geol. Soc. vol. ix. p. 353; and de Koninck, Bull. Acad. Roy. Sc. Belg. vol. xiii. pt. 2. p. 415.

§ See Strzelecki's 'Australia,' Foss. Fauna, Morris; M'Coy, Ann. Nat. Hist. 1847; Lonsdale, Descrip. of the Corals, MS., sent to me whilst the second edition was in preparation.

‖ The numerous fossils found in the Victoria Colony are considered by Mr. Selwyn, the able Government Surveyor, to be either of Lower Silurian age, or belonging to the zone which I now term Llandovery Rocks (Edinb. New Phil. Journ. n. s. vol. i. p. 171; and Quart. Journ. Geol. Soc. vol. xiv. p. 533).

¶ Memoir by the Rev. W. B. Clarke, Quart. Journ. Geol. Soc. Lond. vol. viii.; see also his collections sent to England, and those at the public Museum of Sydney.

** Quart. Journ. Geol. Soc. vol. xvii. p. 7 &c.

leled with the Lower Silurian by Logan and the American geologists * are there based on unfossiliferous slates, limestones, and sandstones, termed 'Huronian,' which, in their turn, repose on the crystalline rocks named 'Laurentian,'—thus showing that America offers the same primeval succession as Britain. (See above, p. 11, and Frontispiece.)

The voyages of our bold Arctic navigators and travellers in search of the lamented Franklin led to the discovery of many well-known Upper Silurian, Devonian, and Carboniferous fossils in limestones amid the polar ice; whilst adjacent to the southern end of America, fossil remains, certainly of Lower Devonian date, have been collected by Darwin in the Falkland Islands.

In few of those regions, however, with the exception of North America (certainly not in the British Isles, where the strata are in many parts much obscured by igneous outbursts), is the order so undisturbed as in Scandinavia and European Russia. There the successive primeval deposits extend over a large portion of the earth in regular sequence and in an unaltered state. Hence, though to the unskilled eye Russia presents only monotonous undulations, chiefly covered by mud, sand, and erratic blocks, its framework exhibits a clear ascending series. The older sedimentary strata, deviating but slightly from horizontality, are overlain by widely diffused masses of those Permian rocks which constitute the true termination of the long Palæozoic period.

The following pages, as before said, will be chiefly devoted to the Silurian stages of the primeval formations. They will be illustrated by woodcuts representing the most important organic remains, and certain pictorial scenes, as well as sections, chiefly taken from my former works. Faithful transfers from the original plates of the 'Silurian System' are also given, with the modern nomenclature of the fossils, and with the addition of the plates of Corals, so admirably described by my valued friend and coadjutor Mr. W. Lonsdale.

Were the next three Palæozoic groups to be equally elucidated, this work would be expanded far beyond the limits to which I must restrict it. The younger Palæozoic (or the Devonian, Carboniferous, and Permian) deposits will therefore be only so far dwelt upon as may be sufficient to give the student a general view, and stimulate him to acquire a fuller acquaintance with them by consulting the various works wherein they are circumstantially described. But even the sketch of them given in this volume will, it is hoped, suffice to show that, while the contiguous strata of two natural groups are intimately linked together by containing species which are common to both, the principal fossils of each are certainly peculiar.

Although few of the mineral changes of the strata can be alluded to, an

* See particularly the works of James Hall and Dale Owen; the Reports and maps of Logan, the chief geologist of Canada; the maps of Lyell, as compiled from the works of the United-States geologists; and the recent general maps of North America, by Rogers and Marcou. See also a table by Professor Ramsay in Chapter XVIII.

endeavour will be made, in the Nineteenth Chapter, to show that gold, however it may now be spread over the surface, has been introduced most abundantly into the older deposits, and chiefly into those of Lower Silurian or older date, and has also accompanied certain eruptive rocks of later date.

Lastly, it is to be observed that, as the true succession of the chief masses of the earlier fossiliferous strata was first detected in England and Wales, so the geological descriptions in this volume will in the first instance be derived from our typical insular examples. A general comparison will afterwards be instituted with the contemporaneous rocks in different quarters of the globe.

The importance of having, through patient surveys, mastered the obscurities which clouded the history of the earlier periods of organic life will thus, it is hoped, be rendered obvious, by showing that we have now obtained as correct an insight into the primeval fossil-bearing formations as we had previously acquired of the nature and history of the younger deposits.

CHAPTER II.

CAMBRIAN ROCKS.

OUTLINES, STRUCTURE, AND ORDER OF THE ROCKS NEXT ABOVE THE LAURENTIAN.—THE RARE FOSSILS OF THE CAMBRIAN ROCKS.—THE ORDER OF CONFORMABLE SUCCESSION UPWARD TO THE 'PRIMORDIAL,' OR LOWEST SILURIAN, ZONE.—SLATY CLEAVAGE.—METAMORPHOSED CAMBRIAN ROCKS OF ANGLESEA.

WITH the exception of the fundamental deposits, termed 'Laurentian,' which, wherever they have been observed, are highly crystalline, the other and overlying ancient rocks in which fossil animals have been detected vary much in structure and outline in different regions. Wherever such masses have remained in a state of comparative quiescence from the period when they were raised up from beneath a primeval ocean, and have since been modified to a slight extent only, they are necessarily unlike those strata which, though formed at the same period and even composed of similar materials, have been penetrated by igneous matter, or subjected to alteration through the action of mechanical pressure, heat, and other agencies.

In Russia *, where some of the older deposits have been but partially hardened since they were accumulated at the bottom of the sea, and have been elevated into merely low plateaux that have undergone no great change or disruption, they have but little resemblance to many rocks of the same age in other countries. When, however, we follow these soft primeval Russian strata to the Ural chain, a region abounding in eruptive and contorted rocks, we find that the beds which on the west consist of mud and sand have there been converted into crystalline schists, limestone in the state of marble, and auriferous quartzites. In Britain, no more striking examples of these changes of physical conditions can be seen than in the territory whose geological structure is explained in this work and the accompanying map. Throughout that portion of the region (Shropshire and Herefordshire) which afforded the types for the Silurian classification, the strata consist of shale, sandstone, and limestone, which, though much more consolidated than their equivalents in European Russia, have been wholly unaffected by that influence which has impressed upon the very same beds, when followed into Wales, a true slaty cleavage. Or if we trace those slates of North Wales across the Menai Straits, we find that they have undergone another change, and have been metamorphosed into a crystalline condition. So again in the United States and British

* Russia and the Ural Mountains, by Murchison, de Verneuil, and von Keyserling, vol. i. p. 26*.

North America, strata formed during the earlier periods are, throughout extensive regions, composed of ordinary sandstone, shale, and limestone; but when pursued eastwards across the undulations of the Appalachian chain to the granitic rocks of the sea-board, or westwards to the Rocky Mountains, these sediments are found to have been converted into masses more or less crystalline.

This is the change which geologists call metamorphism, and which was alluded to in the First Chapter.

It will presently be shown that the comparatively low and unaltered hills of Shropshire and Herefordshire, and some adjacent tracts of Wales, present to the student, in an intelligible manner, a succession of strata, which has been with much difficulty deciphered amidst the hard, rugged, metamorphic, and crystalline formations of the same age in North Wales—even when most of the obscurities had been removed by the labours of the eminent persons who, from Professor Sedgwick downwards, have toiled in the arduous task of bringing the geology of that region into order.

In Russia, the Silurian rocks form either wide level plains or low plateaux; whilst in other countries, where they have been heaved up into mountains, they have a rounded outline, especially where they consist of schists, originally composed of mud, the fine grains of which have given rise to equable atmospheric attrition. When, on the contrary, the shale and schist have been changed into hard slates, the sandstone into quartz-rock, or the earthy limestone into crystalline marble, and particularly if the beds be highly inclined and penetrated by igneous rocks, then sharp peaks or abrupt cliffs and gorges are dominant. Thus it is that the same ancient strata of different regions put on so many different external forms. In South Britain they are, necessarily, most varied in districts which, like those of North Wales and Cumberland, have had their outlines diversified by the intrusion of igneous rocks.

Observation has now taught us of what materials the fundamental rocks of different countries consist. In Scandinavia, particularly in the central and northern parts of Norway, there is every reason to believe that, as in British North America, Bohemia, and the North-west of Scotland, crystalline rocks of Laurentian age underlie all the deposits to which the terms Cambrian and Silurian can be applied. In Bohemia, however, as in Great Britain and portions of North America*, the lowest zone containing Silurian remains ('Zone primordiale' of Barrande) is underlain by very thick basements of earlier sedimentary accumulations of Cambrian age, whether

* In North America the Huronian rocks are, as far as known, azoic. Ranging along the northern borders of Lakes Huron and Superior, they disappear in Wisconsin and Minnesota beneath the next succeeding formation, the Potsdam Sandstone, or lowest set of strata in which Silurian fossils are known. This 'Huronian System' of Logan is mapped in detail in the Atlas of the Geol. Report of Canada, 1863–5, where it is shown that the Lower Silurian rocks are separated from the Laurentian by eleven zones of these Huronian schists, quartzites, conglomerates, chert, and limestone, thus presenting a full equivalent of the Cambrian strata of Europe. See also Dr. Bigsby's elaborate comparison of the Cambrian and Huronian rocks, Quart. Journ. Geol. Soc. vol. xix. p. 36 &c.

sandstone, schist, or slate, which, though occasionally not more crystalline than the fossiliferous beds above them, have as yet afforded only rare indications of former beings.

This is the important fact to which attention is now directed; for in such instances the geologist appeals to strata which have undergone little or no alteration. In this enormous pile or series of early subaqueous sediment, composed of mud, sand, or pebbles, the successive bottoms or shores of a former sea, all of which had been derived from preexisting rocks, he has been unable, after many years of research, to detect more than a very few traces of former creatures. But lying upon them, and therefore evolved after them, other strata succeed, in which clear relics of a primeval ocean are discernible; whilst these again are everywhere succeeded by deposits containing many organic remains of a more advanced nature. In this way, evidences have been fairly obtained to show that the rocks bearing the name of Laurentian and Cambrian constitute the sterile natural bases of the rich deposits termed Silurian.

The hypothesis, that all the earliest sediments have been so altered as to have obliterated the traces of any relics of former life which may have been entombed in them, is therefore opposed by examples of enormously thick and often finely levigated deposits beneath the richly fossiliferous rocks, in which, if many animal remains had ever existed, traces of them must have been detected.

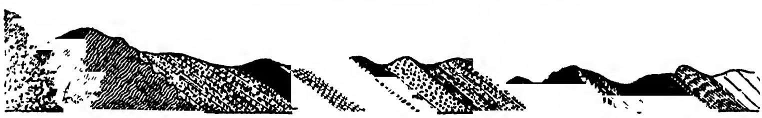
Few words need here be said of those crystalline masses from which in numerous regions the materials of some of the older sediments have been derived. Passing over the consideration of the most ancient granites, and other igneous or molten rocks, of which we cannot have distinct evidences, it has been shown that there are also strata (the Laurentian), now in a crystalline state, which either lie under or have been raised from beneath deposits of Cambrian and Silurian age.

So long as there was no indication of animal remains in such fundamental and crystalline strata, I speculated on their having been formed at a period when the heat of the crust of the earth was antagonistic to the existence of living beings; but with the discovery, in the Laurentian gneiss, of the Foraminifer Eozoon before alluded to, the term 'Azoic,' as applied to this the most ancient formation which has been brought to light, has necessarily been set aside. Still, we are not to suppose that the almost entire absence of organic remains in the Laurentian rocks is due to their crystalline character only; for, in ascending to the next great system in the geological order, we have as yet been unable to detect any striking advance in the creatures which lived during the next very long period. This evidence, though negative, is all the more important inasmuch as in many regions the clay-slates and sandstones of this age, which lie beneath all the richly fossiliferous Silurian formations, are scarcely at all altered or metamorphosed. Proceeding upwards in our researches, we find

that such ancient grits and schists, evidently deposited by water from the waste of previous rocks, are succeeded regularly, and without disorder, by other strata, differing little from the former in composition, in which, at various points of the surface of the globe, and at the same level or horizon, we obtain distinct relics of animals of a higher organization. Once introduced to these well-defined creatures in the 'Primordial Zone' of Barrande, or true Silurian base, the explorer meets thenceforward with an abundant supply of organic remains in all the formations which were successively accumulated.

The accompanying diagram explains at a glance this generalization, as established by an appeal to the structure of every well explored country, where the rocks exhibit the several terms in this long primeval series.

GENERAL ORDER OF THE PRIMEVAL STRATIFIED ROCKS.



The strata marked 1 are the Laurentian or oldest known deposits, which have been formed out of some preexisting rocks, and contain the Eozoon. In No. 2 (the 'Cambrian' of the British Geological Surveyors), feeble indications only of former life have been detected. The overlying accumulations, 3, 4, 5, 6, 7, and 8, stand for the principal formations into which the Silurian System, with clearly developed and abundant life-groups, is divided. The granite, whether intrusive or metamorphic, is *x*.

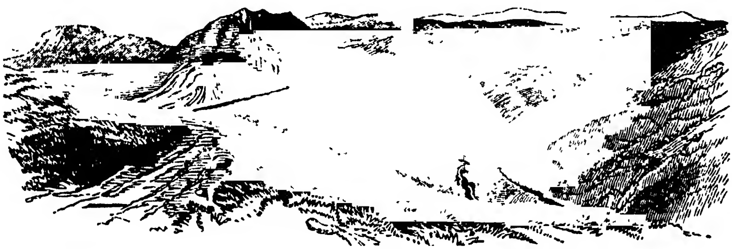
It may here be noted that in no part of England and Wales have any strata been proved to be of more remote age than the Cambrian, No. 2 of the above diagram—though in Scotland the still lower or true basement rocks exist, as has been already stated.

Cambrian or Basement Rocks of the Silurian Region, and their equivalents in Wales. (See Map and its accompanying Section, colour No. 1.)—Let us first review the older rocks in the ascending order, as they were first studied in the western tract of Shropshire, where the lowest strata containing well-defined fossils are seen to repose upon a vast mass of still older and little altered deposits, in which slight traces only of former life have of late years been detected. It will afterwards be shown how the same succession prevails in the slaty regions of Wales, to which the Silurian classification was subsequently applied.

The northern portion of the original Silurian Region, or the south-western part of Shropshire, is marked by a group of hills which presents to the eye an outline and a vegetation strikingly different from those of the surrounding elevations. When examined in relation to the contiguous formations, this mountainous mass is found to be composed of the most

ancient sediments of England and Wales. Bearing the name of 'the Longmynd,' these round-backed hills, which flank the western side of the road from Ludlow to Shrewsbury, attain heights varying from 1400 to 1600 feet above the sea. Ranging from N.N.E. to S.S.W., they rise boldly out from beneath the surrounding Silurian deposits, of which they form the mineral axis.

The annexed woodcut conveys some idea of their form to the spectator looking from one of the transverse openings on the eastern slope towards the valley of Church Stretton. The elevations perceived beyond these hills are, first the Caradoc ridge, then the Wenlock Edge; the Clee Hills appearing faintly in the distance.



THE LONGMYND*.

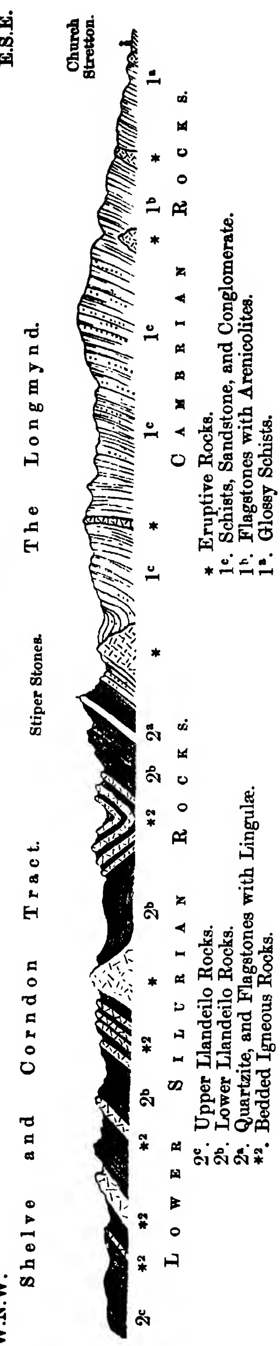
The lowest strata of the Longmynd, or those forming the base of their eastern escarpment, range along the western side of the Stretton valley. They are thin, fragile, glossy schists or clay-slate, with two or three minute layers of siliceous limestone, each scarcely exceeding an inch in thickness. These beds, partially interfered with by bosses of eruptive rocks, dip to the W.N.W., and are overlain by a vast and regular series of hard, purple or plum-coloured, greenish, and grey schistose flagstones and siliceous grits. The whole of this series can be well observed in order of superposition along the banks of the small brook which descends by the Carding-mill to Church Stretton, and in other parallel transverse gullies. Quartz veins occur here and there; but on the whole these strata consist simply of sandstone rock, both schistose and gritty, and often finely laminated, in which the lines of deposit, and even the rippled surfaces of the beds, are distinctly visible, the mass being but slightly affected by slaty cleavage.

The rocks of the Longmynd proper, highly inclined to the W.N.W., are overlain in that direction by other masses of very considerable dimensions, including purple sandstones, conglomerates, and grey schists, which range

* This sketch, and several others relating to this tract, which were made use of in the publication of the 'Silurian Sytem,' were drawn by that sound geologist, the late Mr. Thomas Webster, many years Secretary of the Geological Society. These drawings were prepared to illustrate a manuscript on the geology of Shropshire, intended for publication by my esteemed friend the late Mr. Arthur Aikin, but which he had put aside for some years, when, perceiving that I had discovered in this region an order of succession which had escaped him and his associate, he kindly placed his materials at my service.

Section from the Longmynd on the E.S.E. across the Stiper Stones to the tract of Shelve and Corndon on the W.N.W.

(From Sil. Syst. pl. 32. fig. 1, &c.)



from Linley to Church Pulverbatch, the highest of them dipping conformably under the remarkable quartzose ridge of the Stiper Stones. With these quartzites and their underlying schists commence the Lower Silurian strata as originally defined.

It is to this huge accumulation of schists, sandstone, grits, and pebbly beds, lying between the valley of Stretton and the Stiper Stones, that the term of 'Unfossiliferous Grauwacké' was first applied by me in 1833, and which was afterwards changed into that of 'Cambrian'*. It is important here to remark that the thickness of these rocks in Shropshire has been estimated, by the Government Surveyors, at not less than 26,000 feet, as exposed in their highly inclined edges, the beds dipping, at the average inclination of about sixty degrees, to the W.N.W.†

The opposite diagram, reduced from my original sections, representing the general relations of these Longmynd or Cambrian rocks to the strata which were first defined as the Lower Silurian types, will convey a

* See Proceedings Geol. Soc. vol. i. p. 475. In this publication of the year 1833, after describing, in descending order, the Ludlow and Wenlock rocks as being underlain by 'Shelly Sandstones' and 'Black Trilobite Flagstones' (the whole united in 1835 under the term 'Silurian'), I thus spoke of the subjacent 'Red Conglomerate, Sandstone, and Slaty Schist,' forming the higher portion of the Longmynd:—"This is a vast deposit of several thousand feet in thickness, consisting of very coarse quartzose conglomerates, which alternate with some schistose beds and much purple-coloured sandstone (the Compound Sandstone of Townsend), the strata of which in Haughmond, Pulverbatch, and Linley Hills, Shropshire, are highly inclined or vertical, in conformity with those of the preceding formation. No organic remains have been observed, by which, and by its very peculiar mineral structure, this formation is shown to be entirely distinct from the preceding (overlying) groups." See also Philosophical Magazine and Annals of Philosophy, 1835, vol. xviii. p. 46; and Silurian System, p. 268, and pl. 32. figs. 1, 2, 3.

† According to the same authorities, the Cambrian rocks at Harlech in N. Wales, which are equivalents of the upper portion, are about 8000 feet thick.

clear idea to the reader of that order which every geologist may examine for himself when he walks from the valley of Church Stretton across the Longmynd to the well marked ridge of the Stiper Stones, and thence into that typical Lower Silurian tract of the Shelve and Corndon district, which will presently be illustrated.

A second diagram, reduced by Mr. Aveline from one of the published large sections of the Geological Survey, and which will appear in the next Chapter, is a satisfactory confirmation of the views which, broached in 1833*, were reiterated in 1835† (when the term Silurian was first applied to all the strata overlying the Longmynd), and were finally and fully developed, with coloured illustrations, when the 'Silurian System' was published‡.

In the 'Silurian System,' as well as in Memoirs published some years previously by the Geological Society, I described the Longmynd rocks in detail, and showed that, besides the strata of mechanical and aqueous origin, there are associated with them greenstones and other intrusive rocks, which had in part altered the deposits they penetrated. It was further stated that some of the altered rocks contained copper veins, and that others had cavities lined with crystals of quartz, and occasionally with bitumen or mineral pitch§. The exudation also of mineral pitch from rocks of the same age and character, both at Haughmond Hill to the north of Shrewsbury, and at Pitchford to the east of that town, was pointed out, as well as the frequent recurrence of thin strings of copper-ore.

The geologist will naturally attach much interest to the occurrence of occasional flakes of anthracite in these very ancient strata, and to their yielding petroleum. For if these substances were formed out of vegetable or animal matter, we can refer to little else than Seaweeds or Annelides as their sources‖.

Neither in the period extending from 1831 to 1835, during which I first explored them, nor in subsequent years, when searched by the Geological Surveyors, up to the time when the first edition of this volume was published (1854), had any traces of organic remains been discovered in these Longmynd rocks; and hence, whilst their position and mineral characters were described, they were still spoken of as 'unfossiliferous,' or as

* Proc. Geol. Soc. vol. i. p. 475.

† Phil. Mag. & Ann. of Ph. 1835, p. 46.

‡ The 'Silurian System' was really issued in 1838, though 1839 is on the title-page. In proof of this, see Lyell's Elements of Geology, 1838, in which the leading data of the Silurian System are quoted from my work.

§ The manner in which certain cavities of these rocks are filled with bitumen and small patches of anthracite (Sil. Syst. pp. 260, 265 *et seq.*), and also the veins of copper-ores which they contain near the junction of the intrusive rocks, are facts worthy of attention.

‖ The origin of the bitumen exuding from the interior of these very ancient deposits is necessarily most difficult of explanation. To satisfy his mind on this subject, the reader may consult with advantage a memoir by M. Abich, in the Acad. Sc. St.-Pétersbourg Bull. Phys.-Math. tom. xiv. nos. 4 & 5, in which the author, insisting upon the intimate connexion between the gases proceeding from mud-volcanos and other volcanic outbursts, dwells on the close geological affinity existing between all such operations, including hot springs, &c., and the different sorts of bitumen, asphalt, &c. M. Abich views petroleum (like that which issues from the rocks of Pitchford and Haughmond Hill: see diagram, Sil. Syst. p. 265) as a compound primitive body engendered in the interior of the globe, whence it rises like carbonic acid, of which the real origin is also unknown.

'having not yet afforded signs of any former beings.' That few animals existed during the formation of these rocks has received support from the experiments of Dr. Daubeny, who has been unable to detect any phosphate of lime in them, though in all the overlying Silurian formations in which animal remains occur there are abundant indications of that mineral. Even in the slender calcareous laminæ discovered by Mr. Salter at Church Stretton, Dr. Percy could not detect any appreciable amount of the phosphate. The determinations of the chemist are thus in perfect harmony with the conclusions of the geologist and palæontologist, in establishing a decrement of life as we descend through the strata forming the crust of the globe. (See Appendix B.) Mr. Salter was so fortunate, however, as to discover traces of animal life in these old sediments. In several courses of the hard, siliceous, purple and grey flagstones, low in the series, and overlain by many thousands of feet of strata in which no fossils have been detected, he discovered certain indications of the existence of animals during the Cambrian period.

The impressions represented in Foss. 2, f. 1, are described as the surface-holes made by Annelides, which, like the Lob-worm of our coasts, formed burrows in the sand. These impressions are distinguished by the name of Arenicolites didyma *. Together with the sinuous tracts or trails of such animals, Mr. Salter also found in the minute markings upon the rip-

FOSSIL (2).

Fig. 1.

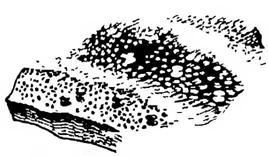


Fig. 1. Burrows of Annelides allied to Arenicola. (Arenicolites didyma, Salter.)

Fig. 2.

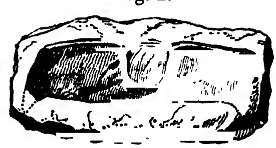


Fig. 2. Part of a Trilobite: Palæopyge Ramsayi, Salter.

pled surface of the strata, evidence of littoral or shore conditions,—an inference which is strengthened by the occurrence of the beds of water-worn pebbles which are seen to prevail in the same series of strata as you ascend towards the summit of the Longmynd.

The fossil next represented (Foss. 2, f. 2) is described by Mr. Salter as the caudal part, or *pygidium*, of a Trilobite, which he named Palæopyge Ramsayi. He considers it to be probably allied to the crustacean Dikelocephalus, described by Dale Owen, from some of the lowest beds of the 'Silurian series' of that author, in the region of Wisconsin, Iowa, and Minnesota (United States)†.

* Journ. Geol. Soc. Lond. vol. xii. p. 248.

† See the work, by Dale Owen, entitled 'Report of a Geological Survey of Wisconsin, Iowa, and Minnesota.' Philadelphia, 1852. The Longmynd fossils are described in the Quarterly Journal of the Geological Society, vol. xii. p. 246, 1856; and vol. xiii. p. 199. A head of the same kind of crustacean has been since found by Mr. Marston, of Ludlow, in the same Longmynd beds, near Minton, and is figured in the Chart of Fossil and Recent Crustacea, by Messrs. Salter, Woodward, and Lowry, 1865.

Desirous of ascertaining whether these faint signs of primordial life might not lead to better evidences of a clear and recognizable fauna, I requested Mr. Salter, accompanied by a zealous young collector (Mr. John Rhind), to re-examine in detail those Longmynd strata in which it appeared likely that any other fossil could be detected. These researches brought to light several highly curious confirmations of the minute tracks or impressions having been made by Annelides.

Let us here observe that the fine aggregation and unaltered condition of these sediments have permitted the minutest impressions to be preserved. Thus not only are the broad wave-marks distinct, but also those smaller ripples which may have been produced by wind, together with apparent rain-prints, as seen upon mud, and even cracks produced by the action of the sun on its half-dried surface. Again, as a further indication that these are littoral markings, and not the results of deep-sea currents, the minute holes left by the Annelides (fig. 1) are most conspicuous on the sheltered sides of the ripples in each slab.

Surely, then, if many animals of a higher organization had existed in this ancient period, we should find their relics in this sediment, so admirably adapted for their conservation, as seen in the markings of the little Sea-worms, accompanied even by the traces of atmospheric action.

In North Wales, where the same Cambrian rocks occur, no fossils, except such as are called Fucoids, have been detected in them. In Ireland, however, where masses unquestionably of the same age prevail in the picturesque rocky tract to the S. and S.S.E. of Dublin, they contain two species of a supposed Sertularian Zoophyte, which, having been detected by Professor Oldham* in the purplish hard schists of Bray Head, received from Professor Edward Forbes the appropriate name of Oldhamia.

Of these two Zoophytes (?), or perhaps Corallines (Stony Algals), one is here figured. It occurs in the hard rocks at Bray Head and Carrick Mac-Reilly, Wicklow, but is most abundant at the last-mentioned of these places. Oldhamia antiqua (Foss. 3), O. radiata, and a variety are carefully delineated by Salter in Ramsay's 'Geology of North Wales,' pl. 26.

This obscure fossil, reminding the naturalist of the Sertularia, may have been really only a Seaweed. With the Oldhamia abundant traces of Annelides, similar to those of the Longmynd, have also been found by Dr. R. Kinahan; and the same observer has attributed certain cylindrical cavities in these rocks to a boring Annelid, called by him Histioderma Hibernicum†. In the sequel, when treating of rocks and their age in the North-western Highlands, similar tubular cavities and infillings, also referred to Worms, as described by Salter, will be mentioned. (See also Quart. Journ. Geol. Soc. vol. xv. p. 368.)

* Then Local Director of the Geological Survey of Ireland, and now the able Director of the Geological Survey of India.

† Trans. Roy. Ir. Acad. vol. xxiii. p. 547. See a clear account, with diagrams, of the zoophytic and worm-like bodies of the Irish Cambrian rocks, by Mr. W. Hellier Baily, F.G.S., in the 'Geological Magazine,' Sept. 1865. Mr. Baily and Mr. Salter follow Dr. Goeppert in doubting the animal character of Oldhamia: so also Dana.

FOSSILS (3).

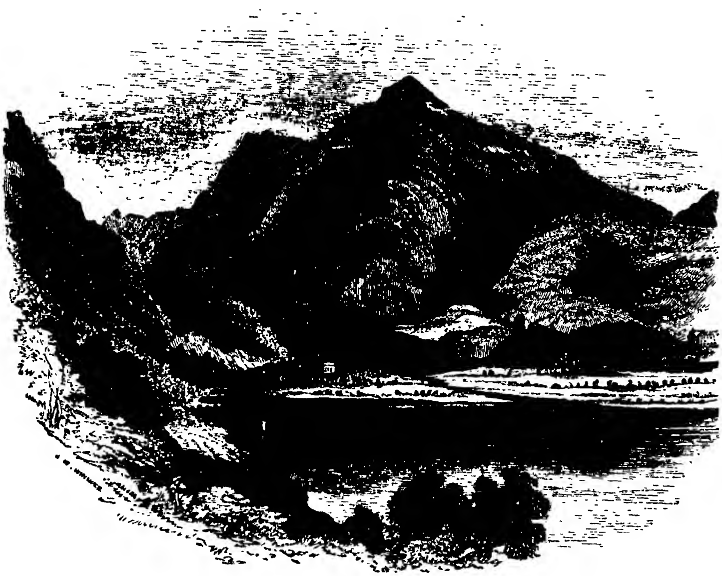
Oldhamia antiqua (E. Forbes), from Carrick Mac-Reilly, Ireland.

(Remains of Fucoids? are occasionally found with this fossil.)

These, then, are the only signs of former life we have yet become acquainted with, after the most assiduous researches in the Cambrian deposits of such vast dimensions, which are often, I repeat, less altered than much younger rocks replete with organic remains.

Let us now mark the same first clear steps in the geological series of North Wales, as worked out by the Geological Surveyors, and indicating a succession similar to that first described in Shropshire.

In the well-known scene figured below, the spectator is supposed to be looking to the Pass of Llanberis, from the lower lake of that name, the heights of Snowdon being in the distance on the right hand. In the foreground, and on both sides of the ruined castle of Dolbadarn, the faces of the cliffs exhibit flexures of the oldest strata here



PASS OF LLANBERIS, FROM THE LOWER LAKE.

visible. These are the purplish and grey slaty rocks (No. 2 of the section at p. 24, and No. 1 of that at p. 26) whose structure and relations in North Wales have been so well described by Professor Sedgwick. Containing the best roofing-slates in the world*, and subor-

* The slates of Llanberis lie in the masses to the left hand of the foreground, and were the property of the late Mr. T. Assheton Smith. Thence they range to the great quarries of Lord Penrhyn, on the N.N.E. A very instructive diagram, representing the curves of the original strata at Llanberis, and the manner in which they are traversed by planes of slaty cleavage, is given by Professor

dinate courses of grit, with rocks of igneous origin intermixed, they are seen to fold over and plunge to the E.S.E., so as to pass under the great and massive succession of schists constituting the distant heights of the Snowdon range. The reader will observe that faint slanting lines have been introduced into the drawing to represent this ascending order, which the geologist can observe for himself, as he examines the sides of the valley in passing from the unfossiliferous slaty rocks of Llanberis, up to the overlying strata (2^a, 2^b, 2^c, of the section below the Map), which, by their imbedded organic remains, are known to be of Lower Silurian age. The rocks in the foreground stand in the place of the Longmynd, whilst the overlying or distant masses are the equivalents of the Stiper Stones, Shelve, and Corndon of the previous section, and even of the Caradoc Sandstone of Shropshire.

A like succession, and a clearer one as regards the exposition of the fossils of the next overlying zone, is seen near Tremadoc on the north, and Barmouth on the south side of the hard Cambrian rocks of Harlech, which represent the upper portion of the Longmynd series. There they also pass under the lowest member of the Silurian rocks—the Lingula-flags—as explained in a diagram prepared for me by Professor Ramsay, for which see the next Chapter.

The generalized coloured section at the bottom of the annexed geological map, also prepared by Professor Ramsay, who, with his associates, Jukes, Aveline, and Selwyn, established the important identification of the slaty rocks of North Wales with their unaltered equivalents in the Silurian Region, will at once render the subject intelligible to the reader (see Preface). In the two fundamental masses, therefore, of the Longmynd, on the east, and of Llanberis and Harlech, on the west, are represented the oldest sedimentary rocks of England and Wales *.

Rocks similar in character to those of the Longmynd, Llanberis, and Harlech, and rising out, like them, from beneath all the Lower Silurian rocks, occur also at and near St. David's in South Wales. There again, as in North Wales, no fossils have been detected in them; but they are conformably overlain, according to observations made by Mr. Aveline and Mr. Salter, as in Shropshire and Merioneth, by strata in which the earliest conspicuous groups of animals have been detected. These British examples are well supported by an analogous succession in Bohemia, where Barrande has indicated the presence of an enormous mass of clay-slate apparently devoid of fossils †, and forming the natural base of his 'Silurian basin of Bohemia.' In that region

Sedgwick, Quarterly Journal of the Geological Society of London, vol. iii. p. 138. For a correct acquaintance with all the faults and fractures of these rocks, the geologist will, of course, consult the subsequently published maps and sections of the Government Surveyors.

* It is also worthy of remark, that in the long transverse section below the Map, extending in a right line over 90 miles of country, the lowest rocks, near each extremity (in Carnarvonshire as in Shropshire), are accompanied by mineralization of the strata. In both, copper and lead ores occur, and in parts of Merionethshire gold also appears. The auriferous conditions of the Lower Silurian rocks of North Wales will be subsequently explained.

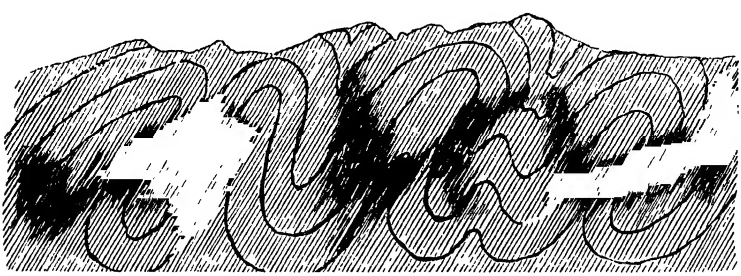
† No fossil, except Eozoon Bavaricum, Gümbel, and some Annelide markings or Fucoids, has been discovered in the vast thickness of clay-slate of this region; whilst Eozoon Canadense is quoted from the underlying crystalline limestone subordinate to the Laurentian gneiss. See Chapter XV.

also, as in Scandinavia, the lowest or earliest traces of those forms of animal life which characterize the Silurian System occur in what that author terms the 'Étage C' or 'Zone Primordiale,' equivalent to the Lingula-flags of the British Isles.

In the next Chapter we shall open out these interesting pages of the history of primordial life, in which we read off with precision how in succeeding strata, accumulated beneath the primeval seas, different animals were added in each zone.

In concluding the subject of the Cambrian rocks, however, a few words must be offered concerning two natural physical phenomena previously adverted to, by which the ancient deposits we are now considering have passed, in North Wales, into states very different from their condition in the Longmynd.

Slaty Cleavage.—The lowest rocks of North Wales are often, as before mentioned, in the condition of true slates. In this respect they present a very different aspect to the strata, of the same age, which constitute the Longmynd. For, although it was remarked in the 'Silurian System' (p. 258) that the Cambrian rocks of the Longmynd had more of a slaty character than any of the overlying deposits of the Silurian region, I pointed out that such cleavage was rude, irregular, and indeed apparent upon a large scale only. The materials composing the rocks of the Longmynd and those of the north-western part of Carnarvonshire, however, are essentially the same. In both, very fine sand and mud, chiefly purplish, greyish, or greenish, have been accumulated in countless thin laminæ of varying colours, with here and there an interstratified and coarser bed.



SLATY CLEAVAGE AND BEDDING. (From Sil. Syst. p. 400.)

The strata in undulation are represented by the curved lines. The fine oblique lines represent the slaty cleavage. (The dark tint represents the portions of a mountain in which the layers of deposit and lines of cleavage coincide.)

They are further surmounted in both tracts by the lowest Silurian strata, containing many of the same fossils, whether in Shropshire, Carnarvonshire, or Pembrokeshire. But still the Welsh rocks differ strikingly from their Shropshire equivalents. The latter, when struck by the hammer, usually break up along their original lines of stratification, like other ordinary

sedimentary rocks; whilst the North-Welsh strata of the same age have been so affected by a distinct rearrangement of the fine particles of mud and sand of which they were originally composed, that they will only split in a direction mostly transverse to the original bedding, cleaving, in fact, into countless, thin, hard plates, all precisely parallel to each other,—in other words, the finest roofing slates. This diagram will explain the distinction between original bedding, as indicated by the stronger curvilinear lines, and the finer slanting lines of the superinduced slaty cleavage, to which the weathered and the jagged edges of some of the mountains of Wales are due.

To whatever force you subject hand-specimens (*c*) of the rock so affected, they will only break in the direction of the fine plates, or, in other words, along the lines of slaty cleavage. Whilst, to the geologist, the original layers of deposit are apparent, as marked by grey, purple, and greenish-coloured different laminæ, the unpractised observer is easily deceived (like many geologists of the old school), and often mistakes these slaty plates for lines of stratification.

To Professor Sedgwick is justly assigned the merit of having first taught the true distinction between slaty cleavage and stratification; and his valuable observations have had a wide application. For this slaty impress has affected not only the oldest rocks of Carnarvonshire, where the finest slates are obtained, but also most of the overlying Silurian formations in Wales; whilst in the original Silurian region the same rocks are, as before said, exempt from it. Slaty cleavage prevails also in the Devonian schists of the Rhine and Devonshire, and in the Lowest Carboniferous strata of Devonshire and Ireland. In short, although this structural arrangement was, in the early days of geology, looked upon as an indication of the great antiquity of the rocks in which it prevailed, and thus led to serious mistakes, the phenomenon is now known to be one which in Britain reoccurs throughout the Palæozoic rocks up to the Carboniferous inclusive.

Those who wish to be better acquainted with this striking phenomenon will do well to consult, in the first instance, the excellent memoir of Sedgwick, who, distinguishing, as before said, cleavage from stratification, referred this mighty change in the strata to some grand operation in which heat and electricity were probably combined; or, in the words of that author, "crystalline or polar forces have re-arranged whole mountain-masses, producing a beautiful crystalline cleavage passing alike through all the strata" *.

Subsequently Professor John Phillips † and Mr. Daniel Sharpe ‡ led the way in propounding another theory, the chief feature of which has been ably sustained and illustrated. Observing that the fossil shells entombed in certain slaty rocks of Wales, Westmoreland, and Devonshire were dis-

* Trans. Geol. Soc. Lond. 2nd Ser. vol. iii. p. 477.
† Rep. Brit. Assoc. 1843, Sect. p. 60.
‡ Quart. Journ. Geol. Soc. Lond. vol. iii. p. 74; and vol. v. p. 111.

torted in directions athwart the original layers of deposit, they inferred that the planes of cleavage which had so deformed the shells had mainly resulted from mechanical forces compressing the sediment at right angles to the lines of cleavage. Mr. Sharpe also, in further illustrating this subject, agreed with Sedgwick in regarding the phenomena of cleavage as being partly due to the action of some unknown and peculiar crystalline force.

Sorby, adopting the mechanical portion of this view, demonstrated its truthfulness * by a series of ingenious experiments, clearly showing how the numerous flattish unequiaxed particles of the ancient mud and sand, out of which slate has been formed, had in all cases aided the great cause, or lateral compressing force, in producing cleavage.

Adhering exclusively to the mechanical theory, Tyndall † further developed the subject. He added the fact, that the production of cleavage was aided by the extension, under pressure, of the minute interstitial cavities which must exist in even the most finely levigated mudstones.

Passing over certain slight differences, these authors, as well as Professor Phillips, agree essentially in affirming that cleavage is due to mechanical causes, or that slates are highly compressed strata.

Whilst it is beyond my present object to dilate upon the forces that produced a phenomenon which, however it may be explained, throws no light upon the order of the strata, I might be permitted to suggest that the geologist may, with profit, follow Sharpe; and, in accepting the suggestions of Sedgwick, he may endeavour to combine them with the purely mechanical theory of Sorby and Tyndall.

If the last-mentioned authors have succeeded (as I think they have) in demonstrating that powerful lateral pressure was a main cause in the formation of slates, I am still disposed to agree with Sharpe, that this cause alone could scarcely have produced such results as we see in the wonderfully minute parallel cleavages of a whole mountain-chain, had not the rocks at the same time been cogently affected, as Sedgwick supposed, by such forces as heat and electricity, combined with vapour, mineral waters, and great lateral pressure ‡.

Not dwelling longer, however, upon this physical problem, I would remind the reader that, once having obtained a clear insight into the distinctions between cleavage and stratification, the geologists who have long and patiently laboured in the Welsh mountains have been enabled to trace the symmetry of deposits, whose slaty composition, and frequent perforation by igneous rocks of various characters, had veiled them in an obscurity from which their equivalents in Shropshire, Herefordshire, Radnorshire, &c., or the unaltered region of Siluria, are almost entirely exempt.

* Edinburgh New Phil. Journ. vol. lv. p. 137; Phil. Mag. 4th Ser. vol. xi. p. 20; *ibid.* vol. xii. p. 127.

† Phil. Mag. 4th Ser. vol. xii. p. 35; *ibid.* p. 129.

‡ The reader who desires to be acquainted with all the phenomena relating to this difficult subject, including the foliation of rocks, must also consult some other important works, viz. 'Geological Observations in South America,' p. 163, by C. Darwin, and D. Sharpe's 'Researches on the Symmetry in the Arrangement of the Planes of Cleavage over large areas,' Phil. Trans. 1852, p. 445; Journ. Geol. Soc. vol. iii. p. 87; and Phillips's Report on Cleavage, Brit. Assoc. Rep. 1857.

Metamorphic Cambrian Rocks.—It has been stated that there are no rocks in South Britain of more remote age than the basement sediments which occupy the Longmynd and the parts of North and South Wales already spoken of. For a long time, indeed, it was believed that the schists and quartzose and felspathic rocks of the Isle of Anglesea, judging from their crystalline character only, were more ancient than any of the masses of the adjacent mainland*. Such, however, is not the case. The preexisting Laurentian rocks, out of whose materials were formed the strata of the Longmynd in Shropshire, of the Llanberis, Bangor, and Harlech mountains in North Wales, and of St. David's in South Wales, having long ago subsided beneath an ancient ocean, and having been covered over by the Cambrian strata of which we now treat, are in the British Isles apparent as dry land only in the North-Western Highlands and Hebrides (see above, p. 9).

CONTORTED CRYSTALLINE SCHISTS AT THE SOUTH STACK LIGHTHOUSE, ANGLESEA.

By the observations of the Government Geological Surveyors, and chiefly y those of Professor Ramsay and Mr. Selwyn, it has been ascertained that he hard and crystalline rocks of North Wales, whether on the coast of arnarvon Bay, ranging southwards to the island of Bardsey, or in the isle f Anglesea, are simply altered portions of the same slates and grits which onstitute the base of the Cambrian deposits in the counties of Carnarvon nd Merioneth. In other words, these old strata have, by the intrusions of

* See the Geological Maps of England and ales, by William Smith and Greenough, and en the edition of the latter published in 1839; as well as the 'Outline of the Geology of England and Wales,' by Conybeare and Phillips.

granite, syenites, porphyry, &c., been altered at some spots into chloritic and micaceous schists, in others into quartz-rock, accompanied by most extraordinary flexures of the beds*. Agreeing with Professor Ramsay, Mr. Selwyn, and my other friends of the Geological Survey, that this is a true explanation of the case, a small sketch is here annexed, to indicate the amount of curvature which these metamorphosed strata have undergone, as seen at the promontory of the South Stack Lighthouse, near Holyhead.

In Anglesea these contorted, crystalline rocks, with their intruded igneous rocks, are overlain by, and associated with, stripes or patches of different palæozoic rocks, of Silurian, Devonian, and Carboniferous age,—thus forming a network which the most experienced geologist might have difficulty in unravelling. Their outlines are very accurately defined in the sheets of the Government Survey Map, and are well and fully described in the 'Geology of North Wales' (1866) by Ramsay, pp. 164, 174, &c. The whole of the bands, with their southward extension for many miles along the edge of Carnarvon Bay, have a direction or strike from S.S.W. to N.N.E., in common with that of the huge buttresses of the Cambrian grit, slate, and sandstone already noticed, which form the western flank of the mountainous range of Snowdon. (See the annexed Map.)

It is to the lowest of these sedimentary rocks of the Silurian Region and North Wales, whether little changed as in the Longmynd, in a slaty condition in Carnarvonshire, or quite metamorphosed in Carnarvon Bay and Anglesea, that the term 'Cambrian' was restricted by the late Sir H. De la Beche and his associates the Geological Surveyors; and I have naturally adhered to a definition which coincides precisely with my earliest conception of the order of succession in the Silurian Region.

The metamorphosis of the Cambrian rocks of North Wales is an example on a smaller scale of the grand changes by which the Lower Silurian rocks of the Highlands of Scotland have been converted into gneiss, mica-schist, &c., as will be explained in the Eighth Chapter.

* The reader will find an admirable account of some of the metamorphosed strata of Anglesea, and their contortions, in a memoir by the late Professor Henslow, published as far back as the year 1822. This work, which may still be read with very great profit, was at that early date a truly remarkable proof of the geological powers of that eminent naturalist and most excellent man. Transact. Cambridge Phil. Soc. vol. i. p. 15.

CHAPTER III.

LOWER SILURIAN ROCKS.

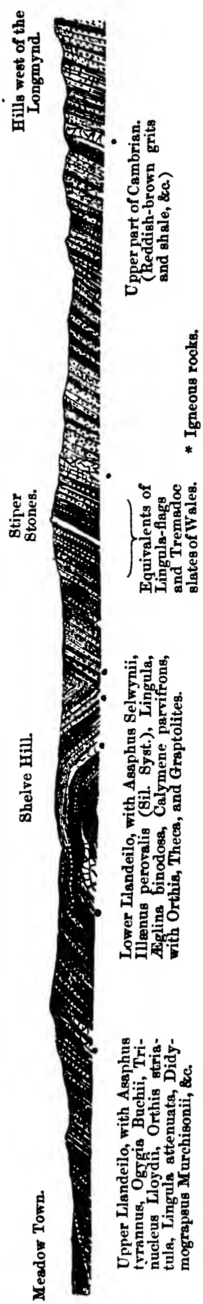
ASCENDING ORDER OF THE STRATA FROM BENEATH THE STIPER STONES TO THE LLANDEILO FLAGS OF SHELVE, IN THE ORIGINAL TYPICAL TRACT OF THE SILURIAN REGION.—SIMILAR ORDER OF STRATA IN WALES FROM THE LINGULA-FLAGS UPWARDS.—THE LLANDEILO ROCKS AND THEIR FOSSILS AS EXHIBITED IN SHROPSHIRE.—THE RANGE OF THE SAME FORMATION WITH ITS CHARACTERISTIC FOSSILS THROUGH WALES.—DISTINCTION BETWEEN THE LLANDEILO AND CARADOC FORMATIONS BY INFRAPOSITION AND BY FOSSILS.—GRAPTOLITES EXCLUSIVELY SILURIAN.

LET us now continue our survey, reverting to that district of Shropshire in which, as has been shown, the Cambrian rocks are more largely developed than in any other part of England and Wales, by examining the fossiliferous strata which, resting conformably upon the upper ledges of the Longmynd, have, from the period of my earliest researches, been classed as the Silurian types. The lowest of these bands is seen beneath the ridge called the Stiper Stones, than which there are few more striking features in the physical geography of the British Isles. Trending in a broken, mural line from N.N.E. to S.S.W., these stony masses appear to the artist like insulated Cyclopean ruins, jutting out upon a lofty moorland ridge, at heights varying from 1500 to 1600 feet above the sea. On reaching the summit of this barren height, the traveller sees below him, to the west, a rapid slope, and beyond it a picturesque hilly tract, the strata of which are laden with Lower Silurian fossils, and diversified by a variety of rocks of igneous origin. In short, he has then within his view the original type of formations which, raised to greater altitudes, and affected by a slaty cleavage, occupy large mountainous districts in Wales.

The geologist who becomes familiar with the protruding bosses called the Stiper Stones perceives that they are outstanding fragments of a thick band of siliceous sandstones, resting upon dark-coloured schist, which I consider to be the equivalent of the Lingula-flags of Wales. Though in parts veined, altered, and fractured, and occasionally passing into crystalline quartz-rock, the Stiper Stones yet form an integral portion of a great schistose formation.

Extending from Pontesbury near Shrewsbury on the N.N.E. to Snead near Bishop's Castle on the S.S.W., or for a distance of upwards of ten miles, these siliceous rocks, together with their inferior black schists, though subjected to several transverse breaks which have given slightly divergent directions to portions of the chain, maintain steadily their relation to the Cambrian or Longmynd series on the east, and to their over-

Section showing the relations of the Lower Silurian Rocks in the West of Shropshire.



lying associated Silurian strata, being conformably underlain and overlain by dark grey schists. In fact, they constitute the natural base of the Llandeilo rocks (Lower and Upper) of the Shelve and Corndon district; and they graduate upwards into these, dipping at high angles to the N.N.W., as represented in the previous general section, p. 26, and also in this diagram, taken from one of the published sections of the Government Survey.

The dark schists, beneath the quartz-rocks, which I place in the same level as the Lingula-flags, have not as yet yielded fossils, and are obscured by intrusions of greenstone.

In the peaks known as the Stiper Stones, the rock has all the appearance of having been altered by the influence of the heat which must have accompanied the evolution of those igneous rocks (chiefly greenstone) which occur on both sides of the ridge*. When most crystalline, it is often intersected by veins of vitreous quartz; and on the broken and weathered fragments are exposed numerous small white facets of quartz crystals, presenting a vivid contrast to the dull brown heath over which they are strewn. In the first of the accompanying sketches†, in which the spectator is looking along the ridge to the S.S.W., the valley on the left hand has been excavated in the uppermost strata of the Longmynd rocks not far to the north of Linley.

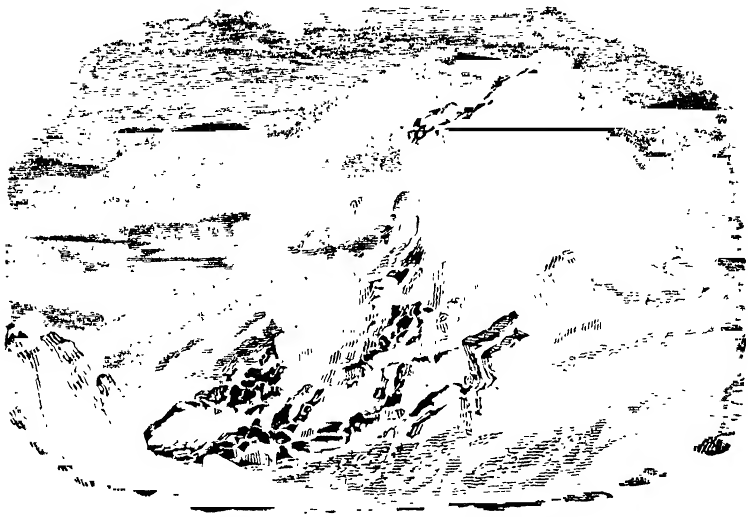
In the following sketch, on the contrary, the protruding rocks are the culminating portions of the rapid slope before adverted to, the strata of which form an integral part of the Lower Silurian Rocks.

The altered condition of these rocks is again instructively exhibited at Granham, to the north of Vessons Coppice, near Pontesbury, where the chief mass is white and crystalline, much fissured, and penetrated by a vein charged

* Several additional bosses of greenstone have been detected by Mr. Gibbs on the eastern side of the ridge; and these I examined when visiting this interesting tract in September 1856.

† From a drawing by the Rev. John Parker of Sweeny.

with anthracite, small flakes of which are disseminated through the rock. In following these ledges of quartz-rock, whether to N.N.E. or S.S.W.,



THE EASTERN FACE OF THE STIPER STONES.

we find them passing into coarse grits and siliceous sandstone. At Nils Hill, close to Pontesbury, where the ridge has subsided to a low elevation, the rock loses much of its altered character, and, being largely quarried as

THE WESTERN FACE OF THE STIPER STONES.

a road-stone, is much more clearly exposed than in the higher parts of its range. The strata dip at the high angle of 60° to 70° to the W.N.W., and are there exhibited in a thickness of from 800 to 1000 feet. The beds, varying in dimensions from a few inches (many of them being 'flagstones') to two and three feet, are separated by way-boards of sandy

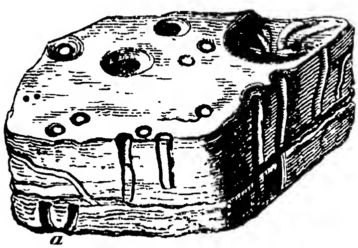
shale, and the lower dividing laminæ are here and there composed of greenish and white unctuous clay*.

On the surface of some of the numerous flag-like beds are broad wavy undulations, and also the ripple-marks so common to many sandy deposits. Together with these are also ramose and twisted forms, some of which are possibly the casts of Seaweeds, whilst others, such as the Chondrites, M'Coy, and Cruziana, d'Orb. (Bilobites, Cordier), may be due to the trails of Annelides, or to the burrows and galleries made by Crustaceans.

Mr. Salter has satisfied me that some of the more tubular cavities and cylindrical bodies are the borings and casts of worm-like animals, and may well represent the Scolithus linearis described by the eminent American palæontologist James Hall,—a fossil which characterizes the Potsdam Sandstone, or lowest Silurian rock of North America. The vertical tubes, curved at their base, and their trumpet-shaped openings, are well preserved, and of a size equal to those made by the common Lobworm on our coasts. These appearances are represented in the accompanying woodcut.

Fossils (4). Annelide-burrows in the Stiper Stones.

A mass of sandstone with the vertical tubes of sand-burrowing Annelides (Scolithus linearis of Hall).

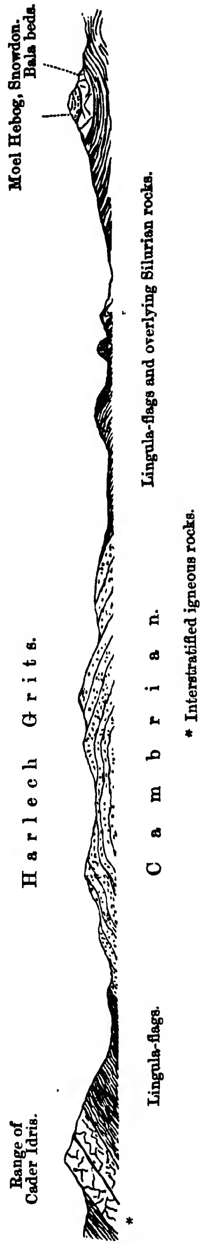


The burrows have two apertures, and are connected below by a loop-like tube, as at *a*.

Numerous fragments of Lingulæ having been discovered, both in the beds immediately beneath, and in those overlying this siliceous rock†, there can be little doubt (especially as they repose upon the rocks of the Longmynd, and graduate upwards into the great mass of the Lower Silurian Rocks) that the band of the Stiper Stones, with its associated underlying black schists, represents, on the whole, the 'Zone Primordiale' of Barrande—that is, the Lingula-flags, upper and lower, of North Wales. It is well to observe that the finely micaceous sandy shale or schist which underlies the more siliceous portion of the series has a great similarity in composition to the beds above these quartz-rocks. In short, the whole of the beds are so knit together, and pass so imperceptibly

* See 'Silurian System,' pp. 284–5, for further details respecting the structure and relations of these rocks.

† These fossils, and many others in the beds immediately overlying the Stiper Stones, were found by Mr. Gibbs, the able collector of the Geological Survey, in August 1856. During this search, I reëxamined the northern portion of my old ground, accompanied by Mr. Gibbs, and had the satisfaction to detect some of these Lingulæ, as well as siliceous flagstones with Scolithi, in an integral part of the Stiper Stones at Eskridge, near Lord's Hill.



S.E. GENERAL ARRANGEMENT OF ROCKS BETWEEN CADER IDRIS AND THE FLANK OF SNOWDON. N.W.

into the superior strata, that no boundary-line can possibly be drawn upon a map, between the rocks composing the Stiper Stones, and the hard, grey, arenaceous, flag-like shale into which they graduate,—the latter, too, containing organic remains, some of which belong decidedly to the Llandeilo formation. (See 'Silurian System,' pp. 268, 270, 274, 280, 283 *et seq.*, and pl. 32. figs. 1, 2 & 3.)

The special Lingula of the Stiper Stones has, it is true, been detected in numerous small fragments only; and, whilst the lower beds in the eastern escarpment unquestionably occupy the same stratigraphical position as the Lingula-flags of Wales, yet, judging from the fragments, it appears that the species of the Stiper Stones is not the prevalent Lingula Davisii of the Welsh slates. When, however, we recollect the extent to which the strata of the Stiper Stones have been altered, and the rarity and broken condition of the Lingulæ detected in them, the specific difference of the one as yet met with is perhaps of no great importance; for, as we shall presently see, there are, in Wales, other forms of Lingula associated with L. Davisii.

It is here, also, to be borne in mind that the Stiper Stones are not less than sixty miles distant from their equivalents near Tremadoc, and that the deposit has changed its character, becoming much more sandy. The plain facts, however, are, that a Lingula-zone in Shropshire, as in Wales, lies conformably upon the Cambrian or Longmynd rocks, and in both tracts, as will soon be shown, gradually passes up into beds charged with the same Lower Llandeilo species of organic remains.

Lingula-flags of Wales.—The Lingulæ which particularly characterize this zone were for a long time unknown even to Professor Sedgwick, who had described the position and mineral character of the slates in which these fossils occur. They were first discovered near Tremadoc by Mr. E. Davis in 1845; and, from their general similarity to some forms of the genus found abundantly in well-known Silurian rocks, he then termed the

slates which contained them Silurian *. The classification followed in this work, which groups the Lingula- (and Agnostus-) flags of North Wales with the Lower Silurian rocks, was first adopted by the late Sir Henry De la Beche and his associates of the Geological Survey. M. Barrande has identified this band with the 'Zone Primordiale' of his Silurian basin, whilst this view has been adopted by M. de Verneuil and geological authors generally on the continents of Europe and America.

The preceding sectional diagram, drawn by Professor Ramsay, gives the general ascending succession both to Moel Hebog on the flanks of Snowdon on the north-west, and to Cader Idris on the south-east. It shows how on each side of an axis or dome of the Cambrian rock of Harlech, or the equivalent of the upper portion only of the Longmynd, there is a zone of Lingula-flags, and how each of these is in its turn overlain by other Lower Silurian deposits with interlaminated igneous rocks. The order in North Wales is therefore similar to that in Shropshire, as exhibited in a preceding woodcut, p. 38. The conformable passage upwards from the basement rock into the Lingula-flags, which is well seen in several other localities, is also here represented as observed at Barmouth.

a. Grits and schists; Cambrian (Upper Longmynd) rocks.
b. Lingula-schists, with imperfect transverse slaty cleavage (white lines).

The Lingula-flags in North Wales are, for the most part, light-grey, glossy, arenaceous schists, associated above and below with black and rusty slates †.

The chief fossil, a flat bivalve shell, the Lingula ‡ Davisii, as figured in the following woodcut (Foss. 5, fig. 1), has a covering which is very horny, and only slightly calcareous, showing that its inhabitant was suited to the conditions of a sea-bottom composed of mud and sand and containing but little lime wherewith to supply the fabric of the thicker shell of other mollusca. It is, indeed, a remarkable fact, that in the vast thicknesses of the inferior or unfossiliferous greywackè before adverted to (p. 28), there is little or no lime, and scarcely the trace of a shell; whilst in these the lowest strata in which calcareous matter is

* Quart. Journ. Geol. Soc. Lond. vol. ii. p. 70.

† For the results of the recent researches by Messrs. Hicks and Salter on the west coast of Pembrokeshire, south of St. Davids, see their memoirs "On the Fossils of the Lingula-flags" in the Journal of the Geological Society, vol. xx. p. 233, and vol. xxi p. 476. Mr. Salter divides the Lingula-flags, palæontologically, into Upper, Middle, and Lower, the last being his 'Mænevian formation,' while the other two are referred by him to the 'Festiniog group' of Sedgwick (*loc. cit.*, and Brit. Assoc. Report for 1865, p. 281 &c.). The fossils collected in Pembrokeshire by Mr. Hicks, and named by Mr. Salter, are now placed in the British Museum and the Museum of the School of Mines. They include some new genera and many new species, the names of which will be interpolated by Mr. Etheridge in the General Table of Organic Remains.

‡ Some palæontologists have separated this shell, under the name of 'Lingulella,' with some doubt, from the common LinguLæ. See Davidson's 'Monograph of British Silurian Brachiopods,' 1866, p. 55.

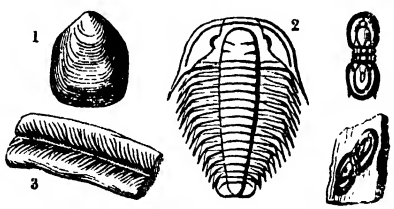
apparent, it has only occurred in such small quantities as to afford a very thin testaceous covering to the few animals of this zone of early life. We shall presently see that when the Silurian fauna became abundant, as in the next overlying strata, it was accompanied by a corresponding development of lime, which served as the material for the construction of the shells of the imbedded Mollusks.

In ascending through the different stages of the Silurian system, it will also be seen that different species of the genus Lingula occurred most frequently at those intervals in which there was a return to similar sedimentary conditions, *i. e.* whenever the muddy sea-bottom was only slightly impregnated with lime.

With the Laurentian gneiss of Canada and other countries there are indeed those great thicknesses of crystalline limestone to which I have already referred. Upon the probable conditions under which the calcareous matter of these primeval rocks was deposited, partly through the medium of low animals like the Eozoon, and partly by chemical precipitation, I would refer the reader to Dr. Sterry Hunt's able memoirs on chemical geology, in the 'Reports of the Geological Survey of Canada,' the 'Canadian Naturalist and Geologist,' the 'Geol. Soc. Journal,' and other works.

Trilobites, or the earliest Crustaceans, abound infinitely more in the Silurian than in the next overlying system of rocks; and the earliest which the labours of geologists have brought to light in Britain are Agnostus, Paradoxides, Conocoryphe, Olenus, Dikelocephalus, and Microdiscus.

FOSSILS (5). LINGULA-FLAGS, NORTH WALES.



1. Lingula (Lingulella) Davisii, M'Coy.
2. Olenus micrurus, Salter.
3. Cruziana semiplicata, Salter.
4. Agnostus princeps, Salter; both of the natural shape and distorted by cleavage.

Besides these fossils, a small Crustacean of the Phyllopod tribe has been found—Hymenocaris vermicauda. A figure of this Crustacean is here given (Foss. 6. f. 1), from specimens in the collection of the Geological Survey. It is plentiful at Dolgelly and Tremadoc, in North Wales, associated with Lingulella Davisii. Tracks of Annelides also prevail, as in the rocks beneath and above the Lingula-flags; sometimes they are of considerable size.

In beds of the same age, near Bangor, have been also found two kinds of so-called Fucoids (p. 40), one of which is, perhaps, the Chondrites acutangulus of M'Coy; the other is a species of the curious genus Cruziana (d'Orbigny), Foss. 5. fig. 3.

With the Lingulæ (or Lingulellæ), of which L. Davisii* is most abundant (L. lepis being rare), there are associated in the lowest courses of these flags several other fossils, of which Agnostus princeps is much the most

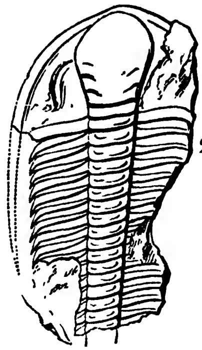
FOSSILS (6). LINGULA-FLAGS, NORTH WALES.

1. Hymenocaris vermicauda, Salter. A Crustacean, probably of the Phyllopod group.

1

Restored outline, from several nearly perfect specimens from Dolgelly.

2



2. Paradoxides Hicksii, Salter, from near Dolgelly, North Wales.

frequent, a similar form (A. pisiformis) being characteristic of this same band in Bohemia and Scandinavia. To the eye of the field-geologist, this little Crustacean seems to be scarcely distinguishable from the Agnostus of the overlying Llandeilo-flags (Pl. III. fig. 8), in which deposit, as will presently be seen, there is a similar association of Lingula and Agnostus. L. Davisii and A. pisiformis are the common species in the Lingula-flags. The other fossils above quoted (Paradoxides and Olenus) are rare in Britain †.

In the recently published volume (iii.) of the Memoirs of the Geological Survey, by Professor Ramsay, Mr. Salter has described at some length, in the Appendix, the various fossils of the two stages of the Lingula-flags, and has stated that Agnostus princeps (the English equivalent of the A. pisiformis of Sweden) occurs in millions, with a new species of Olenus, in the lowest of these. He has also shown the exact place of the Paradoxides of which the locality was unknown when the last edition of 'Siluria' was published. This fossil has been found both at Dolgelly and in Pembrokeshire, at about one hundred feet above the lowest black Lingula-slates. The Hymenocaris has also been found abundantly. Now, as in these deposits the Orthis lenticularis of Dalman, a wide-spread Silurian fossil, is also found abundantly with Lingula and Agnostus, we see how difficult it is to separate these strata in general classification from the rest of the Silurian rocks.

* This little Brachiopodous Shell has often been so much affected by the pressure to which the schistose and cleaved rocks abounding with it have been subjected, that it has assumed the form of several distinct genera, such as Tellina, Modiola, and other Bivalve Shells.

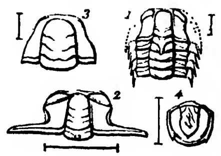
† See Angelin's 'Palæontologia Scandinavica,' Pars I.

Geologists who desire to consult a clear and comprehensive view of the equivalents of the British zone of the Lingula-flags, as well as the whole group of the Silurian rocks, as exposed in Bohemia and Scandinavia, should read a memoir entitled 'Parallèle entre les Dépôts Siluriens de Bohême et de Scandinavie,' by M. Barrande, in which that author shows the exact parallelism of all the beds of the Silurian basin of Bohemia with those of Scandinavia, as indicated in the 'Regiones' (or Stages) of M. Angelin. By reference to the existing distribution of submarine animals, he satisfactorily explains why the species of Crustaceans and other animals, detected in Silurian tracts not distant from each other (the strata of which were simultaneously accumulated), often differ, though the generic types agree. This interesting topic, bearing on the ancient hydrography of Europe, will be considered in a succeeding Chapter.

Small species of Olenus are also found in the lowest fossiliferous strata of another British tract. In the black schists on the western flanks of the Malvern Hills, strata which I had termed Lower Silurian, Professor Phillips detected three species of this genus, viz., O. humilis, Foss. 7. f. 1; O. bisulcatus, f. 2; O. scarabæoides (O. spinulosus, Ph.), f. 3. To these my late friend Mr. Hugh Strickland made the interesting addition of the Agnostus pisiformis, Linn., Foss. 7. f. 4, a fossil known in the oldest Silurian schists, or alum-slates, of Sweden, and there also associated with Olenus. This old fossiliferous stratum rests, in Scandinavia, on a sand-

FOSSILS (7).

1. Olenus humilis, Phillips.
2. O. bisulcatus, Phillips.
3. O. scarabæoides, Wahl.?
4. Agnostus pisiformis, Linn.



Trilobites from the Black Schists of the Malverns.

stone in which no other remains but Fucoids have been detected. In the equivalent underlying sandstone at Malvern (the Hollybush Sandstone and Conglomerate), Dr. Holl*, Dr. Grindrod, and others have discovered some fossils,—Scolithus, Trachyderma antiquissimum (Salter), Serpulites fistula (Holl), Obolella Phillipsii (Holl), Lingula squamosa (Holl), Orthis lenticularis (?), Ctenodonta, Theca, and Lituites. The black Olenus-shales are overlain by light-coloured shales containing Dictyonema† sociale (Salter), first detected in the Malvern area by the Rev. W. S. Symonds, of Pendock. These Dictyonema-shales occur also at Pedwardine, near Brampton-Bryan, in Herefordshire.

M. Barrande again, in the 'Zone Primordiale' of Bohemia, on the same low horizon of life, found Agnostus, Paradoxides, Conocoryphe, and other Trilobites, several of which have only of late years been discovered in our islands. (See Chap. XV.) For a full understanding of this important branch of the subject, reference must be made to the admirable work of M. Barrande, 'Le Bassin Silurien de Bohême.' This most remarkable and truly philosophical monograph is a monument of the talent and perseverance of the author, during a long residence in a foreign land, and exhibits a surprising combination of palæontological knowledge with a faculty of accurately delineating the structure and arrangement of rocks.

The researches of Mr. Salter amid these older rocks of Wales have enabled him to distinguish the two zones of Lingula-flags, and to work out *in situ* their characteristic fossils. He finds that the upper portion of the Lingula-flags (with which he parallels the Black Schists of Malvern above mentioned), besides containing Lingula Davisii and Agnostus, is charac-

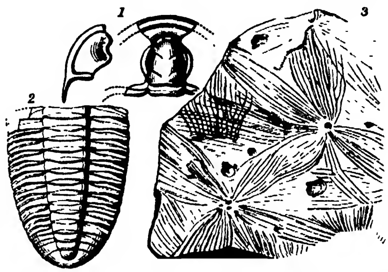
* Quart. Journ. Geol. Soc. vol. xxi. pp. 89, 101, &c.

† A newly discovered generic form, exceedingly interesting as showing a probable connexion between the Fenestellidæ and Graptolites. Its texture is horny. Its distribution in North Wales is described in Mr. Salter's Appendix to Professor Ramsay's 'Geology of North Wales,' p. 246 &c.

terized by other fossils, such as Conocoryphe invita (Foss. 8. fig. 1), C. depressa (fig. 2), Dictyonema sociale (fig. 3), together with a small Orthis and Olenus alatus, Beck, a Scandinavian species.

These fossils occur at Penmorpha and Y-Wern near Tremadoc, and along the base of Moel-y-Gest; where a black slaty layer has been detected in this zone, with a surface covered by the Dictyonema above noted, indicating an undisturbed state of the former sea-bottom. Near Maentwrog and Ffestiniog the same layer has been traced, overlying the lighter-coloured and more arenaceous mass of the Lingula-flags; and, both by its darker colour, and by exhibiting for the first time, in the series of strata, a Polyzoon and an Orthis, with the Agnostus pisiformis, this bed seems to be linked on to the lowest part of the Llandeilo Flags, into which it

FOSSILS (8). UPPER LINGULA-FLAGS, NORTH WALES.



1. Conocoryphe invita, Salter.
2. Conocoryphe depressa, Salter.
3. Dictyonema sociale, Salter; a Polyzoon allied to Fenestella, and the oldest yet known of the group.

graduates conformably, through shaly and schistose beds, charged with Lingulæ, Trilobites, and other Silurian fossils. These schists and flagstones have been described on lithological grounds as 'Tremadoc Slates' by Prof. Sedgwick; and subsequently Mr. Salter, obtaining from them a large series of organic remains, ranked them as two distinct formations, the Upper and Lower Tremadoc Slates. The distinction, however, of the latter from the Lingula-flags proper is difficult to be drawn; and I still adhere to the classification put forth in the last edition of 'Siluria,' and regard the Upper Tremadoc slates as passing into and forming the lower part of the Llandeilo formation, because that band is charged with the Trilobites Asaphus and Ogygia, so characteristic of those strata.

The minute subdivisions of the Lingula-flags and their associated slates, as worked out in North Wales, must be studied in the above-mentioned new volume of the Geological Survey (p. 244 &c.), in which the valuable researches of Messrs. Homfray and Ash, in elucidating the fossils of this 'Primordial Zone' of Barrande, as also the recent successful labours of Mr. Hicks* in Pembrokeshire, are duly noticed by Mr. Salter.

In South Wales, the Cambrian or Longmynd (lower?) rock at St. David's

* See also Quart. Journ. Geol. Soc. vol. xx. p. 233; vol. xxi. p. 476; Report Brit. Assoc. for 1865, p. 281 &c.; and above, p. 42. The 'primordial' fossils found at St. David's will be all enumerated in the Table, Appendix A.

is also seen to be overlain (unconformably), on the north-west and south-east, by a zone of flags containing Lingula Davisii, which is well exposed in Whitesand Bay (see Map),—followed on the north-west by black schists, flags, and slates, representing the mass of the Llandeilo series. Thus, whether we examine North or South Wales, we ascend gradually from the same bottom rocks as those of the original Salopian or Shropshire tract, through strata which afford the earliest well-defined remains of animal life.

This great series of Lingula-flags, so well developed in Wales, is the zone which, in Bohemia, through the enlightened researches of M. Barrande, has proved to be the basis of all Silurian life, and which therefore received from him the name of "Primordial." It is indeed clear that the Fauna of this zone merits all the importance attached to it by its eminent founder, since we have now ascertained that, such as he has described it, the group exists in America, Scandinavia, Belgium, and Spain, as well as in the British Isles and Bohemia.

Llandeilo Formation in Shropshire and adjacent part of Montgomeryshire.—Although this formation obtained its name from the town of Llandeilo in Carmarthenshire, where the greatest number of its characteristic Trilobites were collected, let us first describe it in the district of Shropshire, since there is no portion of the British Isles where a clearer exposition can be seen of the ascending order from strata containing the earliest signs of former life up into deposits teeming with organic remains. The subjacent strata which we have been considering do not, indeed, rise to the surface at or near Llandeilo; and hence the description of the formation near that town is deferred.

During my early researches in Shropshire, I observed certain fossils within a few hundred paces of the Stiper Stones; but many more important organic remains have been since detected close up to that striking ridge. In addition to the clear stratigraphical order which is there exhibited, we now indeed possess fossils for the perfect elucidation of each band as we proceed upwards from the Stiper Stones to the other Silurian deposits (see the sections, pp. 26 & 38).

The strata into which the siliceous grits of the Stiper Stones graduate upwards are slightly micaceous grey flagstones, usually weathering to a brownish colour, and alternating with more schistose and darker-coloured beds. On the whole they are of uniform texture, as seen in any of the deep combes which indent the western side of the ridge of the Stiper Stones *. Thus in the transverse opening in Lord's Hill near the Snailbatch Lead-mine †, or in the deep hollows of the Crow's Nest, Black Hole, Mytton Dingle, and Perkins' Beech, the strata, being scarcely at all inter-

* See Section at p. 24; and Map of the Geological Survey, Sheets 60 and 61.

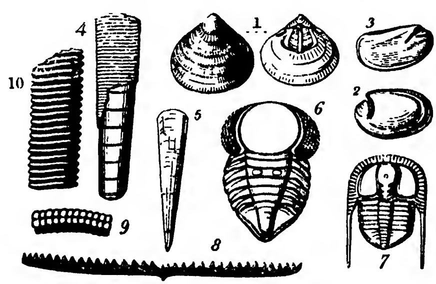
† The reader who desires to obtain information respecting the lead-mines of this tract, which occur in these Lower Silurian rocks, must consult the 'Silurian System,' pp. 277 *et seq.* In this work my chief object is to present a clear idea of the age and sequence of the deposits. The associated igneous rocks, however, and the vast interpolated sheets of volcanic grit which begin to show themselves very low in the order of the strata, and particularly in this tract of Shropshire, will be described in the next Chapter.

fered with by igneous rocks, are observed to succeed each other with the utmost regularity, all having the same strike and dip as the Stiper Stones on which they rest. Of these transverse sections, that of Mytton Dingle is certainly the most expressive; for, in addition to the great depth of this combe, its northern side presents a series of lofty-pinnacled rocks, the beds dipping symmetrically under each other to the W.N.W., through a thickness of not less than 3000 feet.

The points nearest to the Stiper Stones at which fossils have been collected, along the western face of the ridge, are on the slopes of Lord's Hill, near the adjacent Chapel, and at the heads of the combes called Mytton Dingle and Perkins' Beech. They are still more abundant, and the species more varied, in the dark, almost black, earthy slates that overlie these flagstones and form the rising ground to the east of the Bog Mine. The same beds are richly fossiliferous a little further south at Ritton Castle, at the mining ground of Cefn-y-Gwynlle to the west of the southern termination of the Stiper Stones, called Heathmont, and at Disgwylfa near Snead. Similar fossils occur, and have been for some time known, in undulations of the same strata considerably to the west—as at the White Grit Mines.

Regarding all these localities as belonging to one and the same zone, the organic remains exhibited in the following woodcut are its dominant forms. They all have a true Lower Silurian *facies*.

FOSSILS (9). FROM THE WEST SIDE OF THE STIPER STONES.



1. Obolella plumbea, Salter. 2. Redonia anglica, id. 3. Ribeiria complanata, id. 4. Orthoceras Avelinii, id. 5. Theca simplex, id. 6. Æglina binodosa, id. 7. Trinucleus Murchisonii, id. 8. Didymograpsus geminus, Hisinger. 9. Encrinite stem (the oldest known). 10. Orthoceras encrinale, Salter.

In enumerating these fossils in the last edition, some valuable additions were made to the few forms previously described. Thus to the Illænus perovalis of the 'Silurian System' (Pl. 23. f. 7), and the very characteristic species, Ogygia Selwynii (Foss. 10. f. 8), were added a new species of Trinucleus, T. Murchisonii (Foss. 9. f. 7), and the very remarkable Æglina, called Æ. binodosa (f. 6), from its invariably presenting a double tubercle on its third body-segment. Among the mollusks, the commonest species is an Obolella, apparently special to this metalliferous

district, and hence termed O. plumbea (f. 1). Besides this, there are the well-known fossils Orthis alata and O. calligramma (Sil. Syst.); and these are accompanied by Redonia and Ribeiria (f. 2, 3); whilst the several species of Orthocerata, to one of which Mr. Salter assigned, at my request, the name of O. Avelinii (f. 4), were no less important augmentations of our knowledge. Again, among those characteristic Silurian animals the Graptolites, besides some previously recognized species (Diplograpsus pristis and Didymograpsus Murchisonii), we find both the divergent and reflexed varieties of the Didymograpsus geminus, a well-known Silurian species in Sweden and Norway. There is also a Fenestella, a Polyzoon differing essentially from the Dictyonema above mentioned (p. 46), and of an expanded cup-like form. There are also other fossils.

Other species, with some of the above-mentioned forms, are found in the equivalent strata in those parts of Wales to which attention will be soon directed.

On the western flank of the Stiper Stones, this the lowest part of the Llandeilo formation contains many interstratified bands of igneous materials, being what were termed by me 'volcanic grit' when this tract was first described, but now more currently known under the term of 'ashes'*. Several striking courses of such rocks are exhibited at Cefn y Gwynlle and various other spots †. These, with bosses of igneous rocks of intrusive character, the chief mass of which is seen in the Corndon Mountain, as represented in the annexed drawing, will be described when the succession of

LOWER SILURIAN TRACT WEST OF THE STIPER STONES (SHELVE, &c.). THE CORNDON MOUNTAIN IN THE DISTANCE TOWARDS THE NORTH.
(From Sil. Syst. p. 271.)

Lower Silurian rocks, interstratified with contemporaneous ashes and lavas, and traversed by eruptive rocks.

organic life in the Llandeilo and Caradoc formations of various districts shall have been explained. Again, this district is eminently metalliferous,

* These are the "green slates" of some German mineralogists. For the German synonyms of the igneous rocks of Wales and the Silurian Region, see the Appendix (C.).
† See Map of Geol. Survey, Sheet 60.

containing many lead-mines which have been worked from the time of the Romans. Such mineral features require more illustration than can be given to them in the present volume; and on this head, and for all local details respecting the igneous rocks, the reader is referred to the 'Silurian System.'

From these lower strata the observer ascends into a thick succession of flagstones of dark-grey and light-blue colours, in parts calcareous, such as those which compose the chief mass of the Llandeilo formation (Section, p. 24).

These beds abound in Trilobites—Asaphus tyrannus, Ogygia Buchii, and Trinucleus being the most frequent,—together with Lingulæ, Graptolites, &c. These and other characteristic fossils will be figured in a woodcut; they are also seen in Plates I., II., III., IV., V., taken from the 'Silurian System.'

The characteristic Trilobites also occur abundantly in flagstones around the town of Llandeilo, and in the adjacent parts of Carmarthenshire and Pembrokeshire, as well as at Builth in Radnorshire, and near Llanrhaiadr in Denbighshire; but, as before said, the beds in which they there lie do not exhibit the relations to underlying rocks which are so clearly exposed in this district of Shropshire.

Now all the strata which are exposed, from the shale or schist beneath the Stiper Stones inclusive to the western edge of this Shelve tract, or to the villages of Chirbury and Meadowtown (Section, p. 38), and which, with the interstratified volcanic ashes, have been ascertained by the Surveyors to have a thickness of about 14,000 feet, were laid down as Lower Silurian in my earliest publications, from the year 1833 onwards. On the other hand, the fossils of North Wales, subsequently shown to be of the same age, had not then even been detected, much less described, although the strata of the tract we have been considering had been paralleled, by means of their principal organic remains, with the Llandeilo formation of Carmarthenshire.

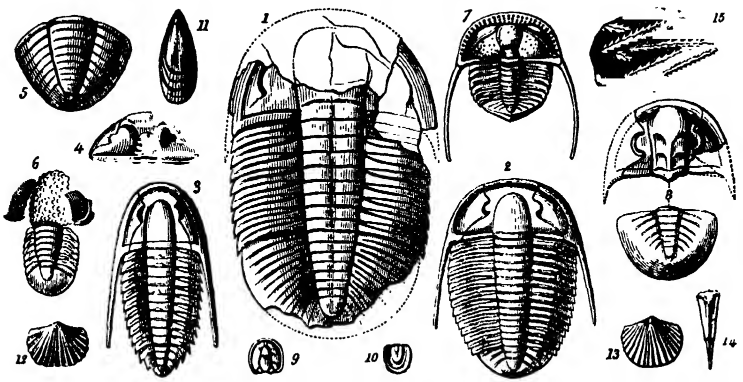
The Llandeilo Formation in Wales.—Having indicated the relations of these 'Black Trilobite Flags' to the subjacent rocks in the typical district of the Silurian Region, let us next consider them in those parts of Wales where the formation is laden with the same characteristic fossils *, and surmounted by other strata which are now ascertained to be the equivalents of the Caradoc Sandstone of Shropshire. In North Wales, strata similar to those which have been described on the west flank of the Stiper Stones (differing only by being in a slaty condition) exhibit a like passage from the Lingula-flags into the mass of the Lower Silurian rocks. There the latter, with many slaty ash-beds, occur beneath the great bands of the porphyritic rocks of Arenig and Ffestiniog, near Tremadoc †, and at Llanfaelrhys, Carnarvonshire, at which places they contain the well-known

* See Memoirs Geol. Survey, vol. iii. Appendix, pp. 256 & 258, for Mr. Salter's complete list of the fossils of the Llandeilo rocks of Wales and Shropshire.

† Termed 'Tremadoc Slates' by Professor Sedgwick in 1847. None of their fossils, however, were described until the year 1851; indeed the greater part were found by Mr. Salter in 1853.

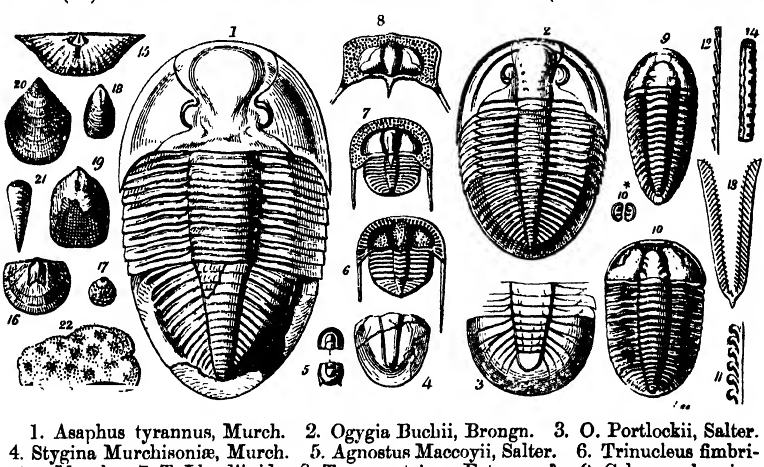
Silurian fossils Orthis calligramma and Diplograpsus pristis, two or three species of Lingula, and Ogygia Selwynii (the species characteristic of the beds on the west flank of the Stiper Stones), with other Trilobites, such as Asaphus affinis (M'Coy), a Trinucleus, and several new species, figured in the following woodcut (Foss. 10).

FOSSILS (10). FOSSILS OF LOWER LLANDEILO ROCKS, NORTH WALES.



1. Ogygia scutatrix, Salter. 2. Angelina Sedgwickii, id. 3. A. Sedgwickii, laterally compressed. 4. Calymene parvifrons, id. 5. Homalonotus bisulcatus, id. 6. Æglina grandis, id. 7. Trinucleus Gibbsii, id. 8. Ogygia Selwynii, id. 9. Agnostus princeps, Salter. 10. Agnostus, n. sp.? 11. Lingulella Davisii, M'Coy, in a compressed form. 12. Orthis calligramma, Dalm. 13. O. remota, Salter. 14. Theca vaginula, id. 15. Diplograpsus pristis, Hisinger.

FOSSILS (11). CHARACTERISTIC FOSSILS OF THE LLANDEILO FLAGS (WALES AND SHROPSHIRE).



1. Asaphus tyrannus, Murch. 2. Ogygia Buchii, Brongn. 3. O. Portlockii, Salter. 4. Stygina Murchisoniæ, Murch. 5. Agnostus Maccoyii, Salter. 6. Trinucleus fimbriatus, Murch. 7. T. Lloydii, id. 8. T. concentricus, Eat., var. δ. 9. Calymene brevicapitata, Portl. 10. C. duplicata, Murch. 10*. Beyrichia complicata, Salter. 11. Graptolithus Beckii, Barr. 12 G. tenuis, Portl. 13. Didymograpsus Murchisonii, Beck. 14. Diplograpsus? teretiusculus, His. 15. Orthis alata, Sow. 16. O. striatula, Emmons. 17. Siphonotreta micula, M'Coy. 18. Lingula attenuata, Sow. 19. L. granulata, Phill. 20. L. Ramsayi, Salter. 21. Theca reversa, id. 22. Monticulipora favulosa, Phill.

Some of these fossils, *e.g.* Angelina, together with Lingulella Davisii and L. lepis, were found by Mr. Salter in the lowest beds of the zone; and these he thinks may be more accurately classed with the upper portions of the Lingula-flags. Ogygia scutatrix, however, found in them, is of a genus as yet unknown in rocks lower than the Llandeilo Flags.

The chief mass of the Llandeilo formation is not well seen around the bases of Snowdon and Cader Idris as surmounting the older strata or Lingula-flags. Stratified igneous rocks with slates are there so dominant throughout a vast thickness, that the type-fossils, such as Asaphus tyrannus and Ogygia Buchii, have not yet been detected, although some associated species of shells occur rarely.

On the eastern flank, however, of the Berwyn Mountains, just as at Llandeilo in South Wales, the formation, though slaty, is characterized by its organic remains, and is seen (Section, p. 60) to pass under other and more arenaceous rocks which form the mass of the Caradoc formation, with which the limestone rocks of Bala in North Wales have been identified. The clear separation of the Llandeilo from the overlying formation of Bala, with which it was formerly associated, will be dwelt upon in the sequel. In the Shropshire district, where the fullest examples of the lowest Silurian deposits are exhibited, the reader will see, by reference to the coloured Map, that the Llandeilo formation is subtended on the north, south, and west by younger Silurian deposits, with which the older rocks are abruptly collocated. To this break, as well as to other discordances of position, attention will be called in other Chapters, it being now desirable to conduct the reader to spots where he may clearly see that the flags containing Asaphus tyrannus, together with Graptolites and other fossils, and identical in their contents and character with the strata of the Shelve tract in Shropshire, are conformably overlain by masses usually more arenaceous, which represent the great body of the Caradoc (or Shelly) Sandstone of the Silurian classification.

In South Wales, the same ascending order that we have followed from the western flank of the Longmynd and in North Wales has been observed, and must be here noticed.

In the environs of St. David's, as before said, purple and green schists and hard grits, long ago identified with the rocks of the Longmynd, and containing traces of so-called Fucoids *, are overlain in Whitesand Bay by slaty flagstones (see Map), in which Lingulella Davisii occurs with many Trilobites (collected by Mr. H. Hicks †). It is in this tract that the connexion of the lowest formation of the Silurian System, or the Lingula-flags and Tremadoc slates, with the Lower Llandeilo is better seen perhaps than in any other part of Wales or England; for here the bluff cliffs, as seen in a beautiful coloured sketch by Mr. C. R. Aston, exhibit a continuous and united succession of dark slates and schists, in which it is as impracticable to

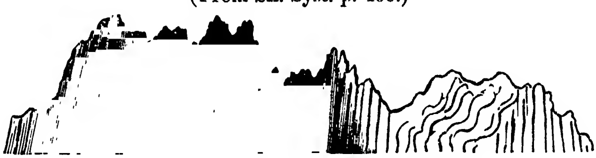
* Sil. Syst. p. 39.

† See Fossils, Chap. IX.

separate the one from the other, lithologically or stratigraphically, as it is to separate the black Alum-slate of Sweden (to be afterwards described) from the overlying Silurian rocks of that country. It is in these cliffs that the largest specimens of Paradoxides have been found by Messrs. Hicks and Salter. These, the lowest fossiliferous strata of the tract, graduate upwards into dark-coloured schists and slates, such as those observed on the west flank of the Stiper Stones, some of the best preserved Trilobites of the lower portion of the Llandeilo-flags having been obtained in this district. Among these are Ogygia peltata, very like O. scutatrix (figured at p. 51), Trinucleus Gibbsii, and another species—together with Agnostus pisiformis, so abundant in North Wales. Again, there is the same passage upwards into black schists, with Trilobites and Graptolites, as at Abereiddy Bay, where the planes of slaty cleavage, as represented by the dark tint in the following woodcut, taken from the 'Silurian System,' coincide with the layers or beds containing the fossils.

This Graptolite-schist is chiefly characterized by Didymograpsus Murchisonii, Beck (Pl. I. f. 1), and Calymene duplicata (Pl. III. f. 6).

LOWER SILURIAN ROCKS IN ABEREIDDY BAY.
(From Sil. Syst. p. 400.)



Coincidence of Slaty Cleavage and Bedding.

To the south of these localities all the Silurian rocks are much obscured, the surface being to a great extent occupied by Old Red Sandstone, Carboniferous Limestone, aud Culm (see Map).

In South Pembroke, the upper and chief portion of the Llandeilo deposit is alone exposed in the cliffs at Musclewick Bay, where it contains Asaphus tyrannus and Trinuclei. The black schists of this age are there insulated by a powerful dislocation, which, on their northern side, has placed them abruptly in contact with the Old Red Sandstone; whilst towards Marloes Bay, or southwards, where younger Silurian rocks form the cliffs, the relations are obscured by a protrusion and overflow of igneous rocks, chiefly greenstone *, as in this diagram.

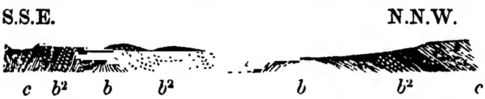
LLANDEILO SCHISTS IN MUSCLEWICK BAY.
(From Sil. Syst. pl. 35. f. 11.)

o. Old Red Sandstone. b. Llandeilo Schists. * Eruptive Rocks.

* See Map. This coast and the dislocations of the strata will be subsequently described.

In quitting this dislocated part of the west coast of Pembrokeshire, and advancing from Haverfordwest to the borders of Carmarthenshire, the geologist perceives that the upper member of the Llandeilo formation puts on a much more calcareous structure. The schists and dark roofing-slates of the Precelly Hills graduate into calcareous flags, which at Llandewi Felfry and Lampeter Felfry become thick argillaceous subcrystalline dark-grey rocks, traversed by veins of white calc-spar, and constituting fine masses of limestone. These beds are largely worked for lime, and are, as far as I know, the only Lower Silurian rocks in Wales now used for such a purpose. The student will have learnt from the previous pages, that throughout all the masses underlying the Llandeilo formation there is little calcareous matter, and an accompanying deficiency of shelly animal remains. In these Llandeilo rocks, however, the original conditions having undergone a considerable change, many more fossils occur. The relations of the strata are here given.

SECTION AT LLANDEWI FELFRY, PEMBROKESHIRE.



b. Llandeilo schists; and b^2 limestones.
c. Caradoc beds.

Underlain by a considerable thickness of black schist (*b*), and surmounted by other strata (*c*), which contain, as will presently be shown, a different group of organic remains belonging to the Caradoc formation, the massive limestones (b^2) of this section are charged with Ogygia, Asaphus, Calymene, Trinucleus, Lingula attenuata, and L. granulata, above figured (p. 51), together with Leptæna sericea, Orthis striatula, and the well-

VIEW FROM DYNEVOR PARK, LLANDEILO, LOOKING TO THE HILLS ABOVE GOLDEN GROVE. (From Sil. Syst. p. 347.)

known Chain-coral, Halysites catenulatus—a fossil which also pervades all the superjacent Silurian limestones of Caradoc, Wenlock, or Ludlow

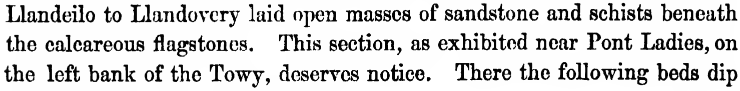
age. When the limestone thins out, its position is in some parts marked by lines of calcareous concretions, in other places by fossils only. At and near the town of Llandeilo, the chief member of the formation consists of calcareous flagstones, in part true limestones, which abound with the above-mentioned characteristic fossils. Extending northwards to Llangadock and southwards to Carmarthen, the Llandeilo flagstones rise in the form of a broken, elliptical mass from beneath overlying strata on both banks of the Towy, thus marking an extensive line of excavation in which that river flows.

The preceding sketch conveys a general idea of the outline of the country, in which most of the Silurian rocks, from the Llandeilo in the foreground to the overlying formations, are exhibited. The calcareous flagstones are seen here on both banks of the river, and the overlying formations in the distance. The foreground is the undulating park of Lord Dynevor, and the chief mansion beyond the valley is Golden Grove, one of the seats of Earl Cawdor. The distant hills are composed of Old Red Sandstone and the lower members of the Carboniferous System.

This succession will be better understood by inspecting the annexed diagram, taken from one of the large sections made by the Government Surveyors, which is quite in accordance with my oldest published sections across the same tract.

SECTION NEAR LLANDEILO. FROM THE LOWER SILURIAN TO THE EDGE OF THE GREAT SOUTH-WELSH COAL-FIELD.

(In this diagram the spectator is supposed to be placed a little south of Llandeilo, looking north-east, or up the Vale of the Towy. Hence the points of the compass are reversed in reference to the following diagram, p. 56.)



b. Llandeilo flags and limestone. *b'*. Llandeilo sandstone, &c. *d*, *e*. Upper Silurian rocks. *f*. Old Red Sandstone. *g*. Carboniferous Limestone. *k*. Millstone-grit.

Subsequently, however, the construction of a railroad from Llanelly by Llandeilo to Llandovery laid open masses of sandstone and schists beneath the calcareous flagstones. This section, as exhibited near Pont Ladies, on the left bank of the Towy, deserves notice. There the following beds dip to the E. by S. at an angle of 75°.

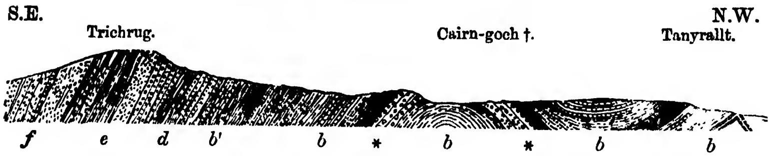
1st. Dark schists with sandstone courses, which graduate upwards into thin schists with nodules. 2nd. Strong bands of hard siliceous light-coloured grits, alternating with thin courses of black shale or schist, which, predominating upwards, contains some remains of Trilobites. 3rd. Calcareous grits and pebble-beds, with remains of Orthidæ and Corals, followed by schists in which Asaphus tyrannus is conspicuous, the group being covered by hard siliceous grits, the masses of which are full of Annelide-trails and of concretions. 4th. Calcareous, dark-coloured, finely laminated flagstones and schists, similar to those at Llan-

deilo and in Dynevor Park, and containing, together with Asaphus tyrannus, the following:—Calymene brevicapitata, Trinucleus Lloydii, Leptæna sericea, Orthis calligramma, &c.

An arched arrangement of the strata is also traceable to Llangadock, where a dome of grits and sandstone, like those of Pont Ladies, emerges from beneath the superior strata, as represented in this diagram.

SECTION NEAR LLANGADOCK. FROM THE LOWER SILURIAN TO THE OLD RED SANDSTONE.

(The spectator is looking to the south-west.)



b. Undulations of Llandeilo schists, flags, and limestone, with interstratified trap *. *b′*. Llandeilo sandstones, &c. *d*, *e*. Upper Silurian. *f*. Old Red Sandstone.

Of like age also are the grits and pebbly beds of Mount Pleasant and other places opposite Carmarthen, from which the fossils Orthis alata, Bellerophon perturbatus, Ctenodonta? lævis, and Stygina Murchisoniæ were obtained during my early labours (1833–4 ‡).

Whilst such are the chief features of the Llandeilo rocks in Carmarthenshire, it is essential to remark that certain sandy beds on the left bank of the Towy (*b′*), ranging by Cairn-goch, which were formerly considered to be Caradoc Sandstone (see Sil. Syst. p. 354), are now known by their imbedded remains to belong to the Llandeilo formation. Along this frontier therefore, notwithstanding an apparent conformity (for the old sections published in the 'Silurian System' scarcely differ from those of the Government Surveyors), there is a great hiatus, as determined by the subsequent labours of Ramsay, Aveline, and Salter. There, on the left bank of the Towy, the true Caradoc group (*c*) is omitted, and the Upper Silurian rocks, with a feeble trace of a sandy rock containing Pentamerus oblongus, at once overlap the Llandeilo formation. This arrangement, by which the Caradoc formation is excluded, extends all along the left bank of the Towy from the environs of Carmarthen, by Llandeilo, and is prolonged far to the north-east.

On the other hand, a natural exhibition of the Caradoc rocks is seen on the opposite bank of the river, where an unbroken ascending series is exhibited, in which both the Llandeilo and Caradoc formations are exposed in conformable apposition. To the north of Llandeilo, the calcareous Trilobite-flags, folding over to the N.N.W., are at once surmounted by a great

† Cairn-goch is a remarkable and rather large British fort, in which the defenders have availed themselves of the smooth faces of a steep anticlinal of these grits, as walls of defence, the ends of the entrenchment being blocked up by loose fragments of the stone.

‡ See Sil. Syst. p. 358, and pl. 25.

thickness of fossiliferous schists and sandstones with some calcareous courses, which clearly represent the original Caradoc Shelly Sandstones, to be described in the next Chapter †.

The Llandeilo flags and schists of Pembrokeshire and Carmarthenshire, charged with the same characteristic Trilobites and other fossils, emerge everywhere from beneath overlying deposits, often of a more arenaceous type, which are of the age of the Caradoc formation. In Carmarthenshire the Llandeilo Flags are associated, as elsewhere, with igneous rocks, both stratified and eruptive, though not on the same scale or of that clear and demonstrative character which is exhibited in the tract of Shelve in Shropshire, and in the district between Builth and Llandegly. By reference to the Map, indeed, it will be seen that it is just where such igneous rocks abound, as marked by bright red colour (*), whether in Shropshire or in Wales, that the Llandeilo formation (2^b) rises prominently to the surface, through the surrounding deposits.

Thus, in proceeding from the Llandeilo tract to the north-east, we first

LLANWRTYD WELLS.

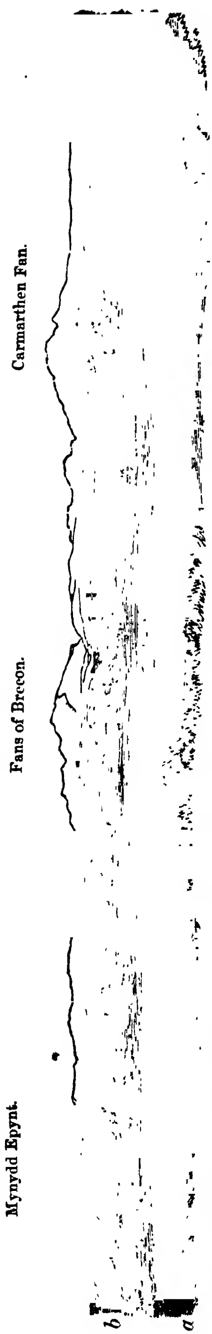
S.E. (From Sil. Syst. p. 336. See also woodcut, Sil. Syst. p. 343.) N.W.

Lower Silurian slaty rocks.

View in a combe below the Baths of Llanwrtyd. (From a drawing by Mrs. Traherne.)

meet with decisive eruptive masses of porphyry and other rocks at and near the Wells of Llanwrtyd in Brecknockshire, and their black schists and

† To the north and west of the Llandeilo district, and all along the western frontier of the Builth country, the boundary-line of my first map of the Silurian Region, which separated the Silurian rocks from the so-called Cambrian of that day, was purely arbitrary. It is merely to be regarded as a demarcation between rocks on the east and south, with which I was acquainted, and a vast *slaty* region on the west and north—which I had not examined, and with whose order and fossil contents I was unacquainted, though in common with Sedgwick and other geologists of the day I believed it to be of older date than the Lower Silurian. Hence I mapped it all as Cambrian. The first rectification of this erroneous view was made in 1842, by Professor Ramsay, who observed that, instead of being succeeded by lower rocks to the north and west, the Llandeilo Flags folded over in those directions and passed under superior strata charged with fossils which Mr. Salter recognized as well-known types of the Caradoc or Bala beds. Hence the whole of those districts of South Wales came to be coloured as Lower Silurian by the Geological Surveyors. (See Map.)



View from the slaty Lower Silurian (*a*) near Llanwrtyd, Brecon, overlooking rounded hills (*b*) of Upper Silurian, with mountains of Old Red Sandstone in the distance, the latter being defined by the untinted outline.

(From a coloured drawing, Sil. Syst. p. 346.)

flags of this age, often highly altered, again prevail. With the loss of calcareous matter, however, the schists of Llanwrtyd no longer exhibit the characteristic Trilobites and Shells of the formation, though they contain some Graptolites. There the beds are so slaty and crystalline that the highly inclined cleavage of the slates, as represented in the foreground of the preceding sketch, is the only feature visible to the unpractised eye,—the real strata undulating or dipping at a much less angle, as represented in the sloping bank on the left of the foreground of the drawing.

When viewed, however, on the grand scale, there is no district more explanatory of the general succession than this very tract between Llandovery and Builth, of which the vignette at p. 57 represents a part. There, if the spectator stands on the summit of the mountain of Esgair Davydd (*b*), above the Baths of Llanwrtyd, he overlooks a wide area to the south-east, and has beneath his feet, and for a certain distance before him, a mass of the lower slaty rocks (*a*) now under consideration; whilst in the dull round hills of the middle ground are spread out the Upper Silurians of the Mynydd Epynt and Mynydd Bwlch-y-Groes, as in this diagram. In the background, the Old Red Sandstone is seen occupying parts of the Mynydd Epynt, and thence rising into the Fans of Brecon and Carmarthen, the highest mountains in South Wales,—the latter 2860 feet above the sea.

In the hilly district extending from Builth on the Wye to Llandrindod and Llandegly (see Map), the Llandeilo formation again rises to the surface in the form of a rugged ellipsoidal mass, throughout which igneous rocks, both stratified and eruptive, prevail. In the sequel it will be shown how that tract, as well as the district of Shelve (both originally described in the 'Silurian System'), presents to the geologist physical

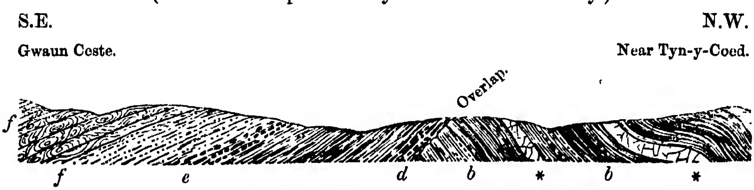
features and rocks similar to those of the grander mountains of North Wales. The environs of Builth and Llandrindod, indeed, afforded a very large portion of the fossils originally published as typical of the Llandeilo rocks *.

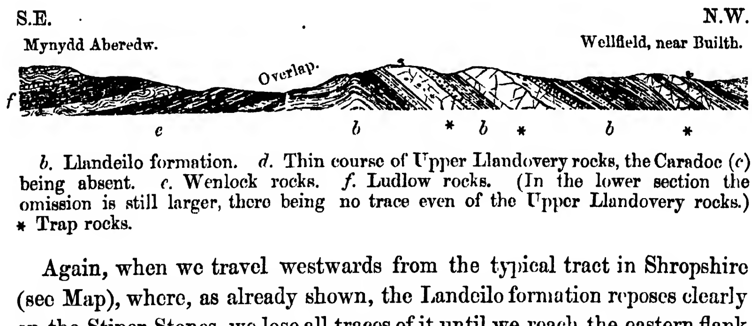
Whether collected at Wellfield and other places near Builth, or in the flagstones north of the Carneddau Hills, Ogygia Buchii, Ampyx nudus, Agnostus Maccoyii, and Lingula attenuata are found in abundance, with beds full of Orthis calligramma and other characteristic shells.

Near Builth, however, as in the west of Shropshire, there is no equivalent whatever of the Caradoc (or Bala) formation. This omission is explained in these two sections, taken from the publications of the Survey, which represent the Upper Silurian, with an occasional thin course of Llandovery rock, reposing upon the edges of the Llandeilo formation.

UNCONFORMABLE RELATIONS OF LLANDEILO FLAGS AND UPPER SILURIAN ROCKS, NEAR BUILTH.

(From Sections published by the Government Survey.)





b. Llandeilo formation. *d.* Thin course of Upper Llandovery rocks, the Caradoc (*c*) being absent. *e.* Wenlock rocks. *f.* Ludlow rocks. (In the lower section the omission is still larger, there being no trace even of the Upper Llandovery rocks.) * Trap rocks.

Again, when we travel westwards from the typical tract in Shropshire (see Map), where, as already shown, the Landeilo formation reposes clearly on the Stiper Stones, we lose all traces of it until we reach the eastern flank of the Berwyn Mountains, the intermediate country being occupied by younger deposits, from the Caradoc formation upwards,--thus clearly indicating that various parts of these regions have been subjected to powerful local oscillations, leaving here and there only the unbroken segments of the whole series of successive deposits, accompanied by the organic remains peculiar to each †.

* So much importance was attached to the locality of Builth, that in an early memoir (Proc. Geol. Soc. vol. ii. p. 23), I termed the deposit 'Builth and Llandeilo Flags.'

† See Professor Ramsay's Presidential Address to the Geological Society for 1863, in which the number and importance of the great breaks in the succession of the Silurian strata of Wales are prominently brought forward and clearly explained.

On the other hand, the annexed diagram * represents how the Llandeilo

Llandeilo and Caradoc Rocks on the East Flank of the Berwyns.

(From a coloured Section, Sil. Syst. pl. 32. fig. 9.)

b. Black slates. *b'*. Llandeilo limestones and schists. *c*. Caradoc sandstones.

formation, consisting of black slates (*b*) below, and of overlying calcareous flagstones (*b'*, occasionally burnt for lime), occupies the eastern slopes of the Berwyn Mountains, as exposed in the gorge of the rapid river Twrch at and below Graig-y-Glyn, and above the small town of Llanrhaiadr. The masses more or less calcareous have a thickness of 400 or 500 feet, and are laden in their lower part with Asaphus tyrannus, Encrinites, and Corals, and in their higher portion with Trinucleus concentricus (T. Caractaci, Sil. Syst.), Acidaspis, Leptæna sericea, Orthis turgida, &c.

All these strata, perfectly identical by their fossils with those of the Llandeilo formation elsewhere, dip at an angle of about 25° to the S.E., and pass with perfect uniformity under that series of shelly sandstones which undulate over this picturesque northern portion of Montgomeryshire. The latter were identified during my early researches with the mass of the Caradoc Sandstones.

This view has been confirmed, the Bala limestone and associated beds being now further known to be identical with these overlying shelly sandstones of the Vales of Meifod and the Tanat †.

The distinctions of this overlying or Caradoc formation, both lithological and zoological, will be described in the next Chapter. It should here, however, be stated that on the flanks of the Berwyn Mountains, as in the valleys of the Ffyrnwy and Tanat, the Lower Silurian rocks have been affected by a transverse slaty cleavage, from which they are usually exempt in the typical tracts wherein the Silurian classification was established.

In thus collating all the results of those explorations of Wales which commenced with the labours of Sedgwick and myself, and have been since extensively and accurately developed by the Government Geological Surveyors, we learn how local elevations have, here and there only, raised to the surface the strata which connect the broken succession of former life. When the Upper Silurian rocks shall have been described, the omissions of certain deposits in some parts, and their attenuation in others, will be placed in tabular apposition to the complete series.

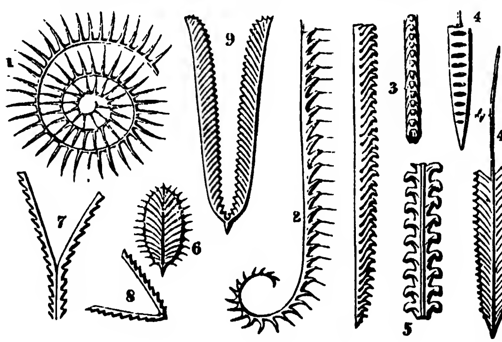
Having spoken of the tracts where the Llandeilo schists and flags are

* This diagram is like the section in the 'Silurian System,' pl 32. f. 9.
† Sil. Syst. p. 306 *et seq.*

clearly recognizable through their position and organic remains, it is not pretended that a line can everywhere be precisely drawn, upon a map, between them and the Caradoc formation; and thus on the accompanying Map the tint 2^b is shaded off into the colour of 2^c. In all such cases of junction and passage, the general term 'Lower Silurian' can alone be with safety applied.

Graptolites.—In terminating this sketch of the Llandeilo formation, a few words may be offered on the fossils called Graptolites, already partially adverted to, and which, wherever they are found, clearly mark the rock to be Silurian. They occur, indeed, in North and South America, Britain, Scandinavia, Germany, Russia, France, and Spain. Abounding in the lowest strata of the Llandeilo formation, which graduate downwards into the Lingula-flags, these Graptolites are specially abundant in the very tract of Shropshire (Stiper Stones to Shelve) on which such stress has been laid as affording the best illustration of a large mass of the inferior strata. They prevail, in fact, throughout the Silurian rocks wherever the nature of the sediment has been favourable to their existence,—that is, in schistose argil-

FOSSILS (12). LOWER SILURIAN GRAPTOLITES.



1. Rastrites† peregrinus, Barrande. 2. Graptolithus Sedgwickii, Portlock. 3. G. priodon, Bronn (G. Ludensis, Sil. Syst.). 4. Climacograptus scalaris, Linn. 4*. Diplograpsus folium, Hisinger. 5. D. nodosus, Harkness (a doubtful species). 6. D. folium, Hisinger (young specimen). 7. Dicranograptus ramosus, Hall. 8. Didymograpsus sextans, Hall. 9. D. Murchisonii, Beck.

laceous strata, or the finely levigated muddy bottoms of the primeval seas. They are supposed by many naturalists to have been Zoophytes nearly allied to the living Virgularia, a creature known only in deep water. Others rather consider these extinct forms to belong to Sertularian Zoophytes, or even to Polyzoa‡. Be this as it may, the geologist has observed that they are found *exclusively* in the Silurian system of life. The whole

† See Geinitz (Verstein. Grauw.-Format.) who, for the sake of uniformity, groups all the Graptolites with a single row of teeth (Graptolithus, Rastrites, &c.) under the name *Monograpsus*. Some forms have been discovered in Canada much more complex in structure than any here figured.

‡ Mr. Salter argues for this latter view of their affinities in the Appendix to the 'Geology of North Wales,' Memoirs Geol. Survey, vol. iii. 1866.

group of these little serrated fossils has been called Graptolithina, and has been divided into several genera, as represented in the foregoing woodcut.

One of these genera, Graptolithus, Foss. 12. f. 2, 3, has teeth or cells on one side only. A second, the Diplograpsus, M'Coy, f. 4*, 5, 6, is distinguished by having a double series of lateral teeth. A third, Rastrites, Barrande, f. 1, has teeth placed like the first-mentioned, but not so crowded together. A fourth, Didymograpsus, M'Coy, has twin branches, f. 8, 9: one of its species, D. Murchisonii, f. 9, is the most characteristic fossil in the Llandeilo Flags of Wales. Some of these forms, as published in the 'Silurian System,' are figured in Pl. I. and Pl. XII. The complex forms which have been more recently discovered constitute other genera, and will be described and figured in Appendix D.

The Diplograpsi, or doubly serrated forms, are chiefly characteristic of the Lower Silurian rocks, D. pristis (D. foliaceus), Pl. I. f. 2, and D. folium, Foss. 12, f. 4* and 6, being ordinary forms. The one-sided species extend from the Lower to the Upper Silurian.

We now know that one of the species of this group, G. priodon, Bronn (G. Ludensis, Sil. Syst.), ranges from the Llandeilo formation to the Ludlow rocks inclusive, having been named 'Ludensis' from its occurrence in the uppermost member of the Silurian series. In no Palæozoic rock younger than the Silurian is, I repeat, the true Graptolite known. Hence, as types, they are most important to the practical geologist, who, in exploring many strata of this age in Cumberland, the southern counties of Scotland, Ireland, Central Germany, &c., meets with scarcely any other fossils †. In Sweden, indeed, Graptolites and Fucoids so abound as to have given a highly bituminous character to the lower strata, which, being also largely impregnated with iron-pyrites, have afforded so much alum as to have procured for them the name of Alum-slates ‡.

Whilst, however, the mere presence of a Graptolite will at once decide that the enclosing rock is Silurian §, it is only by finding the genera of these animals which display a double set of serratures, as in several of the above figures, that, in the absence of signs of the order of superposition, the field-observer may presume he is examining the lower division of the system.

† Dr. Beck of Copenhagen described the few species of Graptolites in the 'Sil. Syst.' M. Barrande has since published a most elaborate and valuable treatise on the Graptolites of his Silurian Basin in Bohemia. Dr. Geinitz, in 1852, systematized all the then known forms of Graptolites, in a work (illustrated by clear and beautiful drawings) entitled 'Die Versteinerungen der Grauwacken-Formation in Sachsen.' One of the most important of the Memoirs on Graptolites is by Professor James Hall, in Decade II. of the Canadian Organic Remains, Geol. Surv. Canada, 1865. Professor Hall inclines to believe them to be related to Sertularians, as also do Professors M'Coy, Dana, and others. See Appendix D.

‡ See an important memoir by the late Dr. G. Forchhammer, on the formation of the Alum-slates of Sweden through the agency of Seaweeds, in the Report Brit. Assoc. 1844, p. 155 *et seq.*

§ It will be seen in the sequel, that these true Silurian types occur in Norway and Sweden in strata of the same age as the Lingula-flags of Britain or the bottom beds of the series.

CHAPTER IV.

LOWER SILURIAN ROCKS (*continued*).

THE CARADOC FORMATION.—SHELLY SANDSTONES OF CAER CARADOC.—GENERAL CHARACTER AND ORDER IN THE TYPICAL SILURIAN TRACT OF SHROPSHIRE.—CHIEF ORGANIC REMAINS AS DISTINGUISHED FROM THOSE OF THE LLANDEILO FORMATION.—GREAT MASSES OF THE SLATY ROCKS OF WALES, INCLUDING THE BALA LIMESTONE, SHOWN TO BE THE EQUIVALENTS OF THE CARADOC OF SHROPSHIRE.—IGNEOUS ROCKS, COTEMPORANEOUS AND ERUPTIVE, OF LOWER SILURIAN AGE.

THAT certain sandstones and shales with occasional calcareous or shelly courses overlie the schistose rocks of the Llandeilo formation in Wales, has already been indicated *. But before we pursue their clear and consecutive relations, let us view those masses of the same age in Shropshire, which, with their fossils, were originally described as a formation younger than the Llandeilo flags, and as underlying all the Upper Silurian rocks. For, this Caradoc formation and its characteristic fossils having been described and named many years before its equivalents in Wales were brought into comparison or their fossils examined, the account of the original type naturally precedes any description of strata subsequently ascertained to be of the same age.

In Shropshire, the Caradoc Sandstone, so named from the ridge on the flanks of which it is well exposed, is cut off, as formerly shown, from the next deposits below it, namely the Llandeilo flags, by the intervention of the Cambrian rocks of the Longmynd (see Map). Whilst a perfectly symmetrical ascending order occurs, as already stated, on the west flank of the Longmynd, from the Cambrian into the lowest of the Silurian rocks, and from them into the Llandeilo formation, in vain do we look on the eastern side of that mountain for any representative of the Stiper Stones and the great Llandeilo formation of the Shelve and Corndon tract (p. 38). The steep slopes of the Longmynd which overhang the valley of Church Stretton exhibit, as already shown (p. 26), the escarpment of the lowest beds of that enormous mass of ancient sedimentary rocks. (See Map.)

Immediately to the east of that valley is seen the line of a powerful fault, the vertical dimensions of which have been estimated (by Professor Ramsay) at not less than 2000 feet, the place of the intervening strata being taken by igneous rocks. The latter having been erupted at a period long after the formation of the original sediments, have altered the schists into hard clay-slates, and the sandstones into quartz-rock. These igneous

* See also general section beneath Map, and local sections (pp. 55 & 60).

and altered rocks, indeed, constitute some of the highest points of the Caradoc Hills. The annexed view, taken from the eastern flank of the

The Lawley. Caer Caradoc. Hope Bowdler. Broccard's Castle. Ragleath.

The Caradoc Range (sketched by Mrs. Stackhouse Acton).

Longmynd, will convey to the reader a good idea of the outline of this eruptive ridge, which trends from the hill of Ragleath on the S.S.W., to the Lawley on the N.N.E., the intermediate hills being those of Hazler and Helmeth; whilst the chief and loftiest mass, or that of Caer Caradoc, gives its name to the whole range. No stronger proof of the great break which here occurs can be given than that on the western flanks of the eruptive ridge, or between the Caradoc formation and the Longmynd, a large mass of Upper Silurian (Wenlock) limestone has been thrown into a vertical and insulated position at Botville*: it is thus wedged in between the Caradoc Sandstone and the Longmynd rocks—the base of the whole sedimentary series (see the following woodcut).

Relations of Caradoc Sandstone to the Upper Silurian Rocks in Shropshire.

N.W. S.E.

Botville. Caer Caradoc. Wenlock Edge.

*d** * *c** *c** * *c** *c* *d* *e* *f*

* Eruptive rocks. *c**. Caradoc Sandstone altered by eruptive rocks. *c*. Caradoc Formation, surmounted by Llandovery Limestone. *d*. Wenlock rocks. *e*. Ludlow rocks. *f*. Old Red Sandstone. *d**. Vertical Wenlock Limestone (Botville).

Striking masses of the altered sandstone are exposed at Cardington, Hope Bowdler, and other places; and this small general section explains the facts.

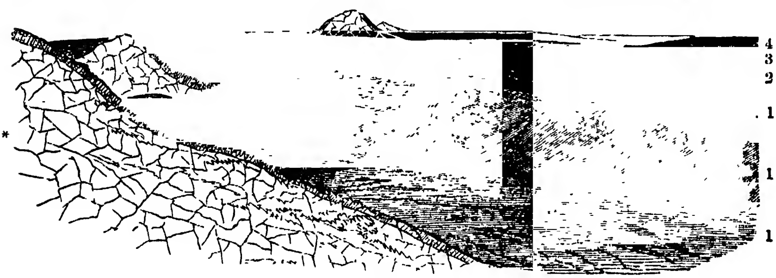
But, notwithstanding all the disorder and change resulting both from a

* See Sil. Syst. p. 231, and pl. 31. f. 4.

great fault upon the W.N.W., and the protrusion of the igneous rocks of the ridge, the various overlying strata, which compose the great body of the Caradoc formation, are observed to succeed each other with perfect regularity.

Proceeding from the eastern flank of the eruptive masses, and receding from the altered strata which adhere to the sides of the syenitic greenstone, felstone, and other rocks* forming the nucleus of the ridge, the fullest and clearest exhibitions of the overlying 'Shelly Sandstones' under review are to be seen in any transverse section which the explorer may examine as he proceeds towards the younger strata of the Wenlock Edge.

The accompanying sketch, reduced from a coloured lithograph in the original work (Sil. Syst. p. 217), will explain better than pages of description how these stratified deposits constitute the well-defined hills to the east of the igneous range.



VIEW FROM THE EAST SIDE OF CAER CARADOC (Sil. Syst. p. 216).

In the foreground is the steep flank of the Caer Caradoc (*), and beyond it to the left is the Lawley, or north-eastern end of the ridge: the Wrekin, another igneous outbreak through the Silurian strata, being on a different parallel, is seen in the central distance. The remainder of this view exhibits, even in the outline of the ground, a true indication of the succession of the various formations as first defined by myself in the years 1832–3.

The slopes marked 1, 1, 1, constitute the chief masses of the Caradoc or Shelly Sandstone, exposed in a thickness of several thousand feet, and lying against the igneous and metamorphosed masses of the ridge (*). The thin zone to which the figure 2 is affixed is the band now termed Llandovery rock; 3 stands for the Wenlock shale and limestone displayed in the Wenlock Edge; whilst 4 represents a part of the distant overlying Ludlow rocks. The spectator has thus before him at one glance, an igneous and metamorphosed ridge, an important member of the Lower

* The details of the mineral structure of the eruptive rocks of the Caradoc range are given in the 'Silurian System.' The predominant rock is hard pinkish felspar or felstone, slightly porphyritic, from which there are passages into varieties of hornstone, syenite, and greenstone; globular concretions with actinolite are not unfrequent, and coatings of quartz-rock or altered sandstone are common (see Aikin, Geol. Trans. i. p. 210; and Sil. Syst. p. 226).

Silurian, a thin intermediate zone representing the Llandovery rocks, to be described in the sequel, as well as all the Upper Silurian group. The flat country in the distance is composed of Carboniferous rocks and New Red Sandstone.

The real order and thickness of the strata exhibited in the sketch, however, is best understood by examining this detailed section.

RELATIONS OF THE CARADOC FORMATION, SHROPSHIRE.

(From the large Section of the Government Survey, made by Mr. Aveline.)

* Igneous rocks. *a*. Sandy shales. *b*. Hoar Edge grits. *c*. Shales. *d*, *d*. Shelly sandstones. *e*. Cheney Longville flags. *f*. Trinucleus shales. *h*. Llandovery limestone. *i*. Wenlock shale.

The strata which compose the great mass of the formation to which the name 'Caradoc Sandstone' was assigned succeed each other in the following order. The lowest beds, which are clearly exposed, dipping away from the intrusive rock (*), are sandy shales (*a*), with some courses of shelly sandstone, in part a bastard limestone, which rise to the surface in the hilly grounds of Acton Burnell, and are thence prolonged by Frodesley to Lawley, or the terminating hill of the eruptive ridge. From that point to the valley (Ape Dale) under Wenlock Edge the succession of the strata is clear. The lowest beds, or sandy shales (*a*), have been hollowed out into a valley. The next overlying strata, as seen in the sketch and section, consist of light-coloured, yellowish, siliceous sandstones, in part coarse grits (*b* in the Section), which occupy the sharp ridge called the Hoar Edge, along which they are extensively quarried, and are seen to plunge at high angles to the south-east.

Another valley succeeds, which has been excavated in softer and more shaly beds (*c*). These, resting upon the siliceous rocks of the Hoar Edge, dip under a second sandstone ridge (*d*), which extends by Chatwall and Enchmarsh to Soudley. These last-mentioned sandstones (*d*) contain layers of fossil shells, which occasionally abound so much as to convert some of the beds into impure limestones. Their prevailing colour is a dirty dull or purplish red; but they are occasionally variegated with brownish, yellowish, and greenish tints. In some quarries not far from Acton Scott they are striped in ribbon-fashion with dark-red and light-green layers; and, being here and there also spotted, they thus resemble both the Old and New Red Sandstones of long-subsequent eras. Along the ridge of Enchmarsh, or at Soudley, they are extensively quarried for use, and are as easily worked as many freestones of the younger formations, reckoning from the Carboniferous sandstones upwards. They are

therefore very peculiar, as long ago remarked*, in being the oldest strata of Britain which present such a comparatively recent lithological appearance—one entirely differing from anything to which the word 'grauwacké' had ever been applied by geologists. And yet, notwithstanding their soft and sectile character, these Caradoc sandstones are laden with a profusion of fossils of the same species as occur in the hard, slaty, argillaceous rocks of large regions of Wales, with which they were truly identified in a few tracts at the period of the publication of the 'Silurian System'†. In short, these shelly sandstones, so near to the Wenlock Edge, and so clearly overlain by a full Upper Silurian series, form essentially a vast portion of the same great Lower Silurian division to which the preceding chapters have been devoted, and whose strata in a more crystalline and slaty state are spread over such large tracts of Wales. The manner in which this result has been fully worked out, amidst the difficulties of so complicated a region, is one of the greatest triumphs of my successors in that diversified Silurian field.

A great thickness of these shelly sandstones is exposed in the sides of the steep lanes leading down from the ridge of Enchmarsh and Chatwell to Cardington, near to the last of which places their uppermost or flag-like finely laminated courses (*e*) have been laid open at Gretton. There a vast abundance of characteristic fossils have been obtained; nearly all of them being forms equally well known in the Bala rocks of North Wales. These beds (*e*) were formerly designated 'Cheney Longville flags,' from their being well exposed at the hamlet of that name on the right bank of the River Onny. They graduate upwards into earthy beds or shales (*f*), which in this district are laden with the well-known Trilobite Trinucleus Caractaci (Sil. Syst.), but for which I afterwards adopted the name 'T. concentricus,' previously given to it by Mr. Eaton of the United States. This beautiful fossil (figured in Pl. IV. and Foss. 46) is found from the base to the summit of the formation, and was named by me after the old British King and the adjacent ridge that still bears his name. Other sections across the strata enumerated may be observed in other traverses of the same district. The clearest of them, as exposed upon the banks of the Onny, between Horderley on the north-west, and Wistanstow on the south-east, was given in detail in my earliest work. It is enough to recapitulate that the lower of the shelly sandstone masses to which we have been calling attention, exhibiting courses of calcareous grit ranging from Horderley to Corton, were described as containing Orthis flabellulum, O. vespertilio, O. unguis, Strophomena expansa, Crinoids, and Trilobites; whilst the superior beds were said to abound in different Orthidæ, particularly Orthis Actoniæ and O. grandis, and Trinucleus Caractaci. The

* Sil. Syst. pp. 216–222.

† The sandstones &c. of Welsh Pool, and of the valleys of the Tanat and Ffyrnwy, were, together with the Meifod rocks, identified by me with these Caradoc Shelly Sandstones (Sil. Syst. pp. 302–307, and pl. 32. f. 9).

Soudley and Enchmarsh beds of freestone were shown to range to the Long Lane and other quarries of sandstones with calcareous courses.

The upper beds, which at Cheney Longville pass up into sandy shale, were described as very fine-grained, slightly micaceous sandstone, of green and dingy olive-green colours, in beds one to six inches thick, and as enclosing here and there shelly calcareous courses, or impure limestones. Looking to the composition of these beds, and others lower in the series and nearer to the eruptive ridge, I inferred that some of them must have been deposited in a sea rendered turbid by volcanic action, so as to form strata which, if fossils were excluded, mineralogists would refer to the 'sandy clay-stone' of Jamieson. I then also stated that they constituted the last lithological term in that series of volcanic rocks of which a description will be given at the end of this Chapter.

The remains of fossils often so abound as to render some of the courses limestones; these have occasionally been burnt for use, and are known to the workmen of the neighbourhood as "Jacob's Stones." When the calcareous matter is diffused in small particles through the mass, the rock becomes a hard calcareous grit, usually of a whitish drab colour, breaking under the hammer with a conchoidal and lustrous fracture. On the banks of the Onny, between Horderley and Wistanstow, there is also a band of impure limestone, formed, however, chiefly of quartzose pebbles cemented by lime.

Some of the most characteristic fossils of the formation are given in this woodcut.

CARADOC FOSSILS (13).

1. Calymene Blumenbachii. 2. Homalonotus bisulcatus, Salter. 3. Phacops truncato-caudatus, Portl. 4. Tentaculites anglicus, Salter. [5. Lingula crumena, Phill.*] 6. Orthis testudinaria, Dalm. 7. O. vespertilio. 8. Strophomena tenuistriata. 9. S. grandis. 10. Bellerophon bilobatus. 11. B. nodosus, Salter. 12. Orthonota nasuta, Conrad. 13. Nebulipora lens, M'Coy. 14. Diplograpsus pristis, Hisinger. 15. Graptolithus priodon.

In addition to the above, the following characteristic fossils are figured in Plates V. to VII. or in the woodcuts of the next chapter:—Orthis elegantula; O. flabellulum; O. Actoniæ; O. calligramma; Strophomena expansa; S. spiriferoides, M'Coy; Leptæna sericea; Modiolopsis orbicularis; M. modiolaris, Conrad; M. obliqua; Bellerophon acutus; Phacops conophthalmus, Eichw.

(The species with no author's name attached were published in the 'Silurian System.')

The cuttings along the Hereford and Shrewsbury railroad laid open

* The Lingula crumena, f. 5, has been placed in the above woodcut by mistake; it belongs to the overlying Llandovery rocks, into which the Caradoc passes upwards in South Wales.

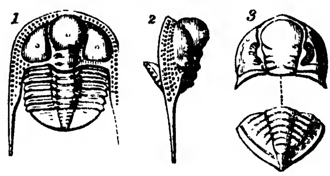
hillocks of this formation between Church Stretton and Marsh-Brook. These rocks consist of purple and red earthy sandstones, in parts micaceous, with partings of green earth, some courses of the shelly beds or 'Jacob's Stones,' and brown calciferous grits. Near Church Stretton the rock is earthy and incoherent, and in it is Diplograpsus pristis, Foss. 12. f. 4, a common Lower Silurian Graptolite, which occurs in the Bala schists in many parts of Wales. This variety of the sandstone is concretionary, exfoliates into balls on weathering, and is full of irregular joints, the surfaces of which are coated with a film of the indigo-coloured oxide of iron so common in the Ludlow rocks.

Others of the fossils which abound in the Caradoc beds are represented by woodcuts in the Chapter IX., and in Plates IV. to VII. of this work; the latter are reprints of the figures published as original Caradoc types from this district. Among them, the geologist who may have explored North Wales will perceive the fossils which occur in many parts of that region, including the casts of Brachiopods he may have collected near the summit of Snowdon.

In the lists of fossils given in the memoir by Salter and Aveline on the Caradoc Sandstone (Journ. Geol. Soc. Lond. vol. x. p. 62), we find that Trinucleus concentricus ranges from the lowest to the highest beds. The Hoar Edge grits contain Phacops apiculatus, Salter, Homalonotus rudis, id., Beyrichia complicata, id., Orthis Actoniæ, O. flabellulum, O. vespertilio, O. testudinaria, and O. calligramma, most of these being species described in the 'Silurian System' as typical of the Caradoc formation. With them, however, is associated the Calymene Blumenbachii, so common in the Upper Silurian division.

Two Trilobites, highly characteristic of this zone, whether in Shropshire or in North and South Wales, which were omitted in the first edition of this work, are given in this woodcut. Trinucleus seticornis, Hisinger (f. 1, 2), is found wherever the Caradoc rocks take on a calcareous or shaly character. Phacops apiculatus, Salter (f. 3), on the other hand, was a denizen of sandy submarine ground, and is plentiful in the sandstones of Shropshire and North Wales.

CARADOC TRILOBITES (14).



The following fossils were found by Mr. Randall, on the banks of the Cownd Brook, in the Lower Caradoc beds as they range towards the Wrekin:—Diplograpsus pristis; D. foliaceus; Orthis calligramma; O. testudinaria; Disema; Lingula attenuata; Palæarca elongata; Orthonota nasuta; Ctenodonta varicosa; Theca triangularis; Euomphalus; Orthoceras; Beyrichia complicata; Trinucleus concentricus.

Ascending to the higher strata through courses of the freestone above noticed, in which some of the same Orthidæ occur with other forms, we reach the thin-bedded 'Cheney Longville flags' of my earlier sections. At one or two localities

where this zone appears at the surface, and chiefly at Gretton, the following copious list has been made out, nearly all the species being also known in the Welsh mountains around Bala, or on the summit of Snowdon &c. Those marked * are most abundant.

Acidaspis Caractaci; Calymene Blumenbachii*; Homalonotus bisulcatus*; Phacops truncato-caudatus*; P. conophthalmus*; Lichas laxatus; Illænus; Tentaculites anglicus*; Serpulites; Cornulites serpularius; Discina oblongata (Portl.); Orthis vespertilio*; O. elegantula*; O. Actoniæ; O. biforata; Strophomena* resembling S. grandis; S. tenuistriata*; S. bipartita*; Leptæna sericea*; L. transversalis*; Modiolopsis orbicularis*; Ctenodonta varicosa*; Murchisonia simplex; Cyclonema crebristria; Conularia Sowerbyi; Bellerophon bilobatus*; B. acutus*; an Orthoceras; with a profusion of fragments of Encrinites, Polyzoa, and several Corals, of which the Stenopora fibrosa and Nebulipora favulosa (var. lens) are the most frequent.

The uppermost band strictly belonging to this formation has been called the Trinucleus Shales. It is charged with the prevailing Trinucleus concentricus, and the Lower Silurian Brachiopod Leptæna sericea, together with Orthis elegantula, Ctenodonta, &c.

In working out the classification first propounded in the 'Silurian System,' I also grouped with the Caradoc formation certain beds of pebbly grits and impure earthy limestone, which, overlying the great mass of the inferior Shelly Sandstone of Shropshire, are seen to pass under the Wenlock formation. Whilst in the first edition of this work I pointed out a discovery made since my early survey, in regard to the physical relation of these strata to the inferior rocks, I still held to the opinion that they ought rather to be grouped with the Lower than the Upper Silurian rocks, and hence I spoke of them as 'Upper Caradoc.' A reexamination of tracts in South Wales, where these deposits are more fully developed than in Shropshire, led me to consider them as a formation intermediate between the two great groups of Lower and Upper Silurian, and as connected through their organic remains with both. They were therefore described in the last edition under the name of 'Llandovery Rocks' (see next Chapter).

Caradoc (or Bala) Formation in Wales.—Adopting the belief prevalent among geologists when the Silurian classification was proposed, that the slaty and crystalline rocks of Wales were, as a whole, of older date than the softer mud-stone rocks on the east, the greater part of the former were referred, without proofs of infraposition, to an older class of deposits. That view was indeed abandoned very shortly after the publication of the 'Silurian System,' or twenty-five years ago,—*i. e.* as soon as it was ascertained that the fossils of Snowdon and Bala were identical with those of previously described Caradoc rocks.

A careful comparison of the fossils of North and South Wales with those of the Caradoc Sandstones of Shropshire, and a reference to certain natural sections, have in fact enabled us to go still further, and to make a separation between the Llandeilo and Bala formations, which, for want of such detailed acquaintance, was not attempted even when the first edition of

this work was published. This distinction is of great interest to myself; for it brings out the value of the original classification of the Lower Silurian rocks, which indicated a great inferior schistose group charged with large Trilobites (Llandeilo), as followed by more arenaceous strata—Shelly Sandstones, or the mass of the Caradoc formation.

Looking at the general section under the Map, the reader will at once see how the beds of Llandeilo age are surmounted throughout North Wales by strata of the Caradoc age, and how the last are followed by other formations, of which hereafter. In truth, this identification of the Bala fossils with those of the Shelly Sandstones of Caer Caradoc has removed all difficulty in applying the Silurian succession to great masses in Wales, the rocks of which, being in a crystalline and slaty condition, are very unlike their unaltered equivalents in Shropshire.

It has now transpired that the physical relations and palæontological distinctions between the Llandeilo flags on the east flank of the Berwyns (the most westerly point which I formerly examined) and the overlying fossiliferous strata of the tract watered by the Tanat and the Ffyrnwy, as given in the 'Silurian System,' were perfectly correct.

In the diagram before given (p. 60) we see how the Llandeilo flags with the Trilobites, Asaphus tyrannus and others, as exposed in lofty crags (Craig-y-Glyn) overhanging the gorge of the River Twrch above Llanrhaiadr, dip under those shelly sandstones of the lower hills of the valleys of the Tanat and Ffyrnwy. The latter strata, though affected, like those on which they rest, by a slaty cleavage, were described as again emerging from beneath Upper Silurian rocks in the environs of Welsh Pool, and were all, as before said, distinctly identified with the Shelly Sandstones of Caer Caradoc. This comparison was a subject of no difficulty to me; for it was evident that the sandstones of Montgomeryshire, with their included courses of impure limestone, including Trinucleus Caractaci, Strophomena expansa, and numerous other fossils, were identical with the shelly sandstones of Caer Caradoc.

In short, through other undulations (see Map and its Sections), these beds extend westwards until they constitute the slates of the summit of Snowdon, where the very same fossils occur as in the low hills of soft shelly sandstone in Shropshire, the district from which such forms were first described.

It appears from the recent publication of the Geological Survey (Memoirs, vol. iii. p. 86) that the Bala beds of North Wales are by no means of such large vertical dimensions as the Caradoc Sandstones of Shropshire; for, abstracting the porphyries, ashes, and other intercalated volcanic rocks, the limestones and sandstones of this age do not present a thickness of more than 1050 feet; whilst those of Shropshire are about 4000 feet thick.

In South Wales we have the same physical order and the same changes in organic life between the Llandeilo and Caradoc groups as are observed

elsewhere. In Carmarthenshire and Pembrokeshire the Llandeilo Flags, with their large Asaphi and Ogygiæ, are surmounted, as before stated, by sandy beds with impure limestone, containing the same species of fossils as those of the Shelly Sandstones of Caer Caradoc.

Seeing that in Carmarthenshire there was no apparent unconformity towards the east and south between the Llandeilo Flags and the Upper Silurian rock under which they dipped, as exhibited in the Sections, pp. 55 & 56, I formerly inferred that the equivalent of the Caradoc Sandstone of Shropshire had locally thinned out to the south and south-east of Llandeilo, or was there represented by certain coarse sandy beds or grits only. Again, detecting scarcely any trace of organic remains to the west and north of the zone in which the Llandeilo flags were dominant, I drew a line of limit on my original map, and termed all the rocks 'Cambrian' which lay beyond the known fossil-bearing zone, stating that the separation of the Silurian from the then supposed Cambrian of South Wales had been effected by assigning to the former those beds which contained, and to the latter those which did not contain, the characteristic fossils (Sil. Syst. p. 360). And yet such sections as were made towards the west and north-west indicated that the strata of Carmarthenshire, on the right bank of the Towy, folded over to the north and west, and constituted a mass of arenaceous and incoherent slaty schists, which were spoken of as lithologically inseparable from the Lower Silurian rocks (Sil. Syst. p. 360).

It is not my object in this volume to describe the mines which occur in the Silurian or other Palæozoic systems; but it may be noticed that the chief mines in Carmarthenshire, or the lead-ores at Nant-y-Moen, north of Llandovery, the property of Earl Cawdor, occur in these quartzose rocks, which alternate with slaty schist. They are now ascertained to be in part the equivalents of the Caradoc Sandstone of Shropshire, and in part of the Llandovery rocks to be described in the ensuing Chapter. In Caradoc quartzites also are situated the old Roman gold mines of Gogofau, in the parish of Llanpumpsant, ten miles west of Llandovery *. In describing these rocks of slaty quartzose grit and sandstone, I accurately assigned to them a dip to the north-west †; and that fact alone ought to have led me to class them as Silurian, since they appeared to overlie the Llandeilo flags. But the slaty condition of the rocks, and the absence of fossils, induced me to refer them to a system unknown to me. A great fault was, indeed, supposed to intervene, to account for this apparent inversion. These rocks were further noticed as containing coarse grits, sandstones, and conglomerates—the latter often appearing as huge lenticular masses.

The only organic remains detected during my partial survey of such strata were a few fragments of Crinoids and Shells, and the Annelide-markings or tracks of marine Worms found near Llampeter, such as the Nereites and Myrianites ‡. These fossils are now known to be common to Silurian rocks in Scotland, Germany, and other parts of the world.

In their laborious and accurate researches, the Government Surveyors established clear proof that, whilst on the left bank of the Towy a great

* See Sil. Syst. p. [illegible], and Mr. Warington Smyth's account of these mines, Records of Geol. Survey, vol. i. p. 480.

† See the woodcut, Sil. Syst. p. 368.

‡ See Sil. Syst. pp. 363, 699, and Chap. X. of this work. Geinitz, of Dresden, who has described these forms, considers them to be soft-stemmed creatures of the same family as Graptolites (Nereograpsus &c.). They may even be due to the superficial burrowings of Crustacea.

RELATIONS OF THE LLANDEILO AND CARADOC ROCKS (SOUTH WALES)*.

S. by E. N. by W.

a. Undulations of Llandeilo flags and slaty shale. *b.* Slaty shales and arenaceous strata with some calcareous courses (Caradoc formation). *c.* Pebbly beds passing up into Llandovery rocks.

portion of the Caradoc formation is omitted, the hilly tracts to the north and west, *i. e.* on the right bank of the stream, which had been called Cambrian, afforded clear indications of a gradual and conformable upward passage from the Llandeilo Flags into schistose beds. These, becoming more arenaceous and siliceous as they rise into higher hills, contain some calcareous courses, the fossils of which are all identical with those of the Caradoc and the Bala rocks.

This section (published on a much larger scale by the Survey) was made, in the year 1842, by Professor Ramsay. The fossils he then collected and sent to London were examined and determined by Mr. Salter.

The great mass of the strata above the Llandeilo Flags, as seen in ascending the Nant-y-Rhibo Brook to Cwm-y-gerwn, consists of dark sandy shale with some calcareous matter, containing the following fossils, all of which are of true Caradoc age: namely, Trinucleus seticornis, His.; Staurocephalus Murchisoni, Barr.; Orthis insularis, Eichw.; O. Actoniæ, Sil. Syst.; O. vespertilio, id.; O. calligramma, Dalm. and Sil. Syst.; Leptæna transversalis, Dalm.; L. quinquecostata, M'Coy; L. tenuicincta, id.; Cyclonema crebristria, id.; and the Chain-coral. Proceeding to still higher ground, extending to Mynydd banc-y-ffair, we meet with other forms; for, while there are still a few Caradoc fossils, such as Orthis crispa, M'Coy, and the remarkable Trilobite Encrinurus multisegmentatus, Portlock, these are associated with the Atrypa reticularis, a shell which uniformly characterizes the higher zone to be presently described under the name of Llandovery Rocks. Again, the highest beds visible in this line of section indicate still more clearly a passage into the Llandovery rocks. Thus in them we detect the Atrypa crassa, Leptæna transversalis, a Rhynchonella closely resembling R. navicula, and a large Heliolites, all unknown in the inferior or true Caradoc strata, one of the fossils of which, however (Orthis insularis), still remains, as if to demonstrate a gradual zoological transition.

On the left bank of the Towy, in the wooded grounds of Llandovery, we again find the Llandeilo beds regularly surmounted by slaty and arenaceous beds, which,

* It was this section (as before stated) which led Sir H. De la Beche and Professor Ramsay to abrogate the hypothetical line formerly drawn between the known Silurian country and the tracts unexamined and unknown by me.

underlying the conglomerates at the base of the Llandovery seriês, are full of characteristic Caradoc fossils. Thus, in Cilgwyn Park, under the conglomerate terrace of Glan Towy, the beds, which are quarried in the demesne, consist of dark-grey, earthy slates, and contain the following characteristic fossils,—identical with those forms which are met with everywhere upon the banks of the Onny, or at Bala:—

Trinucleus seticornis; Asaphus Powisii; Illænus Bowmanni, with species of Calymene and Cybele; Orthis spiriferoides, M'Coy; O. biforatus; O. insularis; Ctenodonta; a Discina? (Patella Saturni of Portlock), a species known at Cheney Longville, and in the Caradoc schists of Tyrone, Ireland; Bellerophon bilobatus; B. nodosus; Theca triangularis, Portl.; Sphæronites balthicus; and a fine species of Pleurocystites, with some of the ordinary Corals.

The same Caradoc beds also range round under Blaen-y-cwm, South of Llandovery. They there contain similar fossils, with the addition of Lichas laxatus, M'Coy, Orthis porcata, id., and Orthoceras ibex, Sil. Syst., now known to range from the Caradoc to the uppermost Ludlow rocks. Further north, between Rhayader and Builth, the Caradoc strata everywhere appear beneath the Llandovery rocks; and at Troed-y-Rhiw the same fossils are obtained, including a peculiar Crinoid, the Pleurocystites, together with the Bellerophons and the Orthoceras vagans so common at Bala.

Thus we have in that tract an unbroken ascending series from the Llandeilo Flags through the Caradoc into those beds with Pentameri which I formerly grouped with the latter formation, and which are, indeed, essentially connected with it.

In Pembrokeshire also, at Llampeter Felfry and Llandewi Felfry, the Llandeilo Flags, constituting the thickest limestones known in the Silurian rocks of Wales, occur, as already stated, in low undulations, dipping under strata which also stand in the place of the Caradoc. (See diagram, p. 54.)

A thin and impure calcareous course, exposed at Sholeshook, near Haverfordwest, and which was formerly classed with the Llandeilo Flags*, is also clearly separated from that deposit, both by superposition and characteristic organic remains. Besides Brachiopods, Trilobites, and numerous Corals common in the beds at Bala, there are also found in it Encrinite-like forms with slender stems and grape-shaped heads, the Sphæronites of old authors (Cystideæ of Von Buch). Some of these will be figured and described in another chapter,—Echinosphærites aurantium and E. balthicus, both common Russian and Scandinavian species, being among the number.

In the vast tracts of Carmarthen, Cardigan, Radnor, and Montgomery, to the west of the original Silurian region, which have been examined by the Geologists of the Survey, and illustrated in their large coloured sections, it is known that few or no rocks older than the Caradoc (or Bala) formation, or younger than the Lower Llandovery rocks of the next chapter, ever appear—even up to the sea-cliffs extending from Cardigan to Aberystwith and Machynlleth (see colour 2^c of Map); so much do the same bands of sandstone and schists (usually affected by a transverse cleavage)

* Sil. Syst. p. 387.

undulate in gentle curves. There are, indeed, proofs, in several tracts, that these rocks, as in the district north of Llandeilo, graduate upwards into the Pentamerus zone of Llandovery, the inferior and larger portion of which belongs essentially to the Lower Silurian division.

When the earliest edition of this work was published (1854), it was still the belief of geologists that the Llandeilo and the Bala formations were one and the same; and, although the inferences which have since been arrived at rest greatly upon the true order of superposition as worked out by Ramsay and Aveline, we are also greatly indebted to the palæontologist (Mr. Salter) who has cooperated in establishing the true sequence. On my own part, I simply claim the credit of having originally placed the Llandeilo formation beneath all the deposits of the age of the shelly sandstones of Caer Caradoc, with which the Bala beds were long after identified. This order was also first pointed out by me in parts of Montgomeryshire and Denbighshire; and it is now applied to the whole of Wales*.

Throughout large portions of North Wales there are, indeed, other evidences of the age of the rocks in question, besides those already adduced on the east flank of the Berwyns. At and near Bala, for example, the sandstones, slates, and limestones are the absolute equivalents of the Caradoc shelly sandstones in Shropshire. The chief limestone of this group, exposed in low hills near the town and lake of Bala, is so impure that it is now never used for burning, and, dwindling away to the S.S.W., is lost among the slaty strata. Another calcareous course, near Hirnant, is simply one of the shelly sandstones of Shropshire. Thus, with the exception of having been affected by a slaty cleavage unknown in the English types of these rocks, the North-Welsh strata are, even lithologically, to a great extent similar to the Caradoc formation of Shropshire.

The fossils of the Bala beds are, indeed, as already said, identical with those of the flanks of Caer Caradoc, there being scarcely a species found in Wales which does not occur in Shropshire.

Sufficient proofs having been now offered of the superposition of the Caradoc to the Llandeilo rocks, and the fossil characters of the two formations having been generally indicated, we might at once proceed to consider the distinctions of the next overlying beds, all of which I once grouped with the Lower Silurian rocks. But, having for some time regarded those strata as an intermediate deposit, the larger and inferior portion of which is naturally connected with the Lower and the higher members with the Upper Silurian, a separate chapter is devoted to them. In the meantime, however, a few pages must be occupied by a sketch of the igneous or volcanic masses which especially abound in the Lower Silurian formations.

* In the first edition of this work I endeavoured, in spite of my old convictions, to accommodate my views to those of my successors, who had regarded 'Llandeilo' and 'Bala' as synonyms, and therefore suppressed my old section from the flank of the Berwyns to Welsh Pool. But in the second edition I reverted to the original details and descriptions given in the 'Silurian System,' which are clear and demonstrative, as before stated, in identifying the great undulating masses of strata in the Welsh region watered by the Tanat and Ffyrnwy rivers, as well as the Welsh Pool ridge, with the shelly sandstones of Caer Caradoc.

Igneous rocks associated with the Lower Silurian.—To make the reader acquainted with the complete aspect and nature of the British Lower Silurian rocks, it is essential to explain how volcanic action affected the bottom of the sea in certain districts during the deposition of those sedimentary strata, and how those strata (particularly of the Llandeilo formation) were also penetrated by powerful eruptions.

In the vicinity of some igneous rocks, the schists and calcareous flagstones have also been filled with mineral veins, and have undergone various changes*. Thus one of the tracts in the original Silurian region where the Llandeilo formation is most productive in lead-ore is the rugged, hilly, district of Shropshire which lies around the village of Shelve and the Corndon Mountain, and extends westward from the Stiper Stones (see Section, p. 26, and Map).

The student of natural phenomena is again specially invited to examine this tract, the ordinary strata of which, and their organic remains, have before been described, because it exhibits all the cotemporaneous formations in North Wales, in hills which are much more accessible than the steep flanks of the slaty, subcrystalline mountains of Snowdon and Cader Idris.

This typical Lower Silurian district was long ago shown by me to contain two classes of submarine igneous rocks,—the one bedded and regularly interlaced with the strata, and therefore formed at the same time with them, the other unstratified and posterior. Each of these is divided into several varieties, for a full acquaintance with which the reader must consult the original descriptions †.

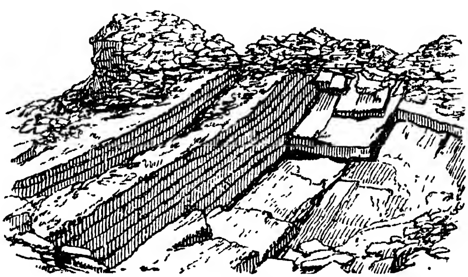
Of the interstratified felspathic ashes ('volcanic grit' of the 'Silurian System'), there are very numerous examples between the west flank of the Stiper Stones, where they first appear in the ascending order, and the picturesque defile of Marrington Dingle near Chirbury on the west, or, in other words, through a space of four to five miles in breadth, and eight to nine miles in length (see Sil. Syst. p. 268).

At the Bog Mine, on the western slope of the Stiper Stones, and therefore in the lowest member of the Llandeilo formation, the mineral veins and adits traverse a vast number of the thin-bedded felspathic grits or ashes, interstratified with the schists and flags charged with Trilobites and Graptolites. Not less than seventeen courses of these igneous rocks are marked in the Government Geological Map of this district (Sheet 60) as occurring in the space of little more than a mile, between the Bog Mine and the environs of Hyssington! Some of these courses are traceable for four miles on their line of bedding. They crop out in parallel rocky ridges, whilst the associated schists and shales have been worn into alternating furrows or depressions. The broadest of these hard felspathic bands, as seen upon the surface, ranges from near Symmonds Castle on the S.S.W. by the Roundtain Hill to Stapeley, beyond which, or between Shelve and Rorington, it is divided into five or six of the thinner courses

* Besides ores of lead and copper, it will be also shown, in a separate chapter, that rocks of this age were rendered partially auriferous in Wales, and largely so in other countries.

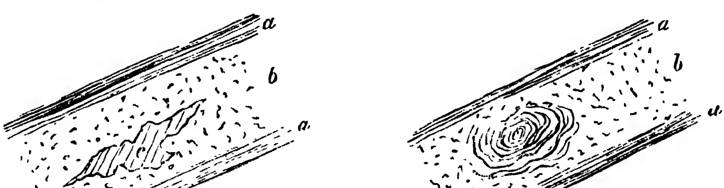
† See Sil. Syst. pp. 269, 324, and *passim*; and for observations on these and other igneous rocks by Mr. D. Forbes, see Appendix (B). See also p. 49.

interlaminated with the Llandeilo Flags. Among the higher members of these stratified tuffs, which were manifestly accumulated under former seas, some of the finest examples are to be seen in the picturesque defile of Marrington Dingle. There the lowest strata, exposed in numerous quarries, are felspar rocks of a concretionary structure, which are surmounted by coarse mottled volcanic grits. The latter consist of a base of lightish and greenish-grey granular felspar, mixed with sand and chlorite, and contain angular fragments of schists and porphyritic greenstones, the whole being arranged in beds from two to four feet thick, and dipping at an angle of about 40°, as expressed in this vignette.



ONE OF THE WHITTERY QUARRIES IN MARRINGTON DINGLE. (From Sil. Syst. p. 270.)

In many other parts of this district, we meet with felspathic agglomerates and ash-beds, or volcanic grits, as well as slaty porphyries with crystals of felspar. Some of these alternate, as before said, in ridges with the schist containtaining Trilobites; others constitute courses of a few inches thick only, and occasionally include fragments of Ogygia Buchii. Organic remains are also found in beds composed almost exclusively of volcanic materials, thus showing that volcanic action was rife at the sea-bottom in which these Lower Silurian strata were accumulated.

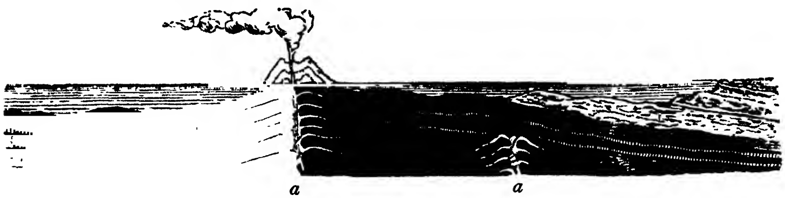


Volcanic Breccia or Ash, *b*, alternating with beds of Schist, *a*, and enveloping other fragments of schist and slate, *c*.

(From Sil. Syst. p. 271.)

Another diagram, taken from the coloured sections on the margin of my old map of the Silurian region, explains theoretically the manner in which, by the action of submarine volcanos, such igneous dejections are supposed to have accumulated. The igneous or volcanic materials are represented by the light-coloured layers, which, issuing from beneath *a*, *a*, alternate

with the ordinary dark-coloured muddy sediment. The diagram further shows how a volcanic cone similar to that of Graham Island (Ile Julia of



Ideal Representation of the manner in which Submarine Volcanic Dejections were probably formed during the Early Silurian Period.

(From bottom of Map, Sil. Syst.)

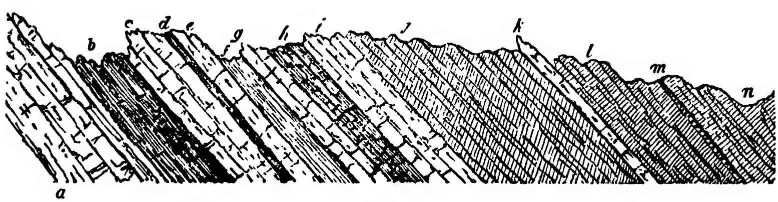
the French) in the Mediterranean, and indicated by the dotted lines, may, after rising into the atmosphere, have disappeared; its scoriæ and ashes having mixed with the ordinary marine mud or sand.

One of the larger masses of eruptive rock, which penetrated the sedimentary and associated volcanic deposits at a subsequent period, is seen in the Corndon Mountain, as expressed in the sketch at p. 49, the undulating ground around it being composed of strata of the Llandeilo formation and beds of felspathic ashes.

Equally instructive examples of the alternations of bedded igneous matter with Lower Silurian strata, and also of posterior eruptions, are seen in the rocky tract of Radnorshire, extending from Llandegley and Llandrindod by the hills of Gelli, Gilwern, and Carneddau, to Builth. This example of felspar-porphyries, which are there regularly stratified, is taken from one of my earliest illustrations.

Alternations of Llandeilo Flags and Schists with Volcanic Grits, exposed in a ravine on the north-west face of Gelli Hill.

(From Sil. Syst. p. 325.)



a. Coarse slaty felspar rock, both porphyritic and amygdaloidal, containing elongated concretions of greenearth. This rock is regularly stratified in beds three to four feet thick, and forms the mass of the hill, rising into the higher ground. *b.* Finely laminated greenish-grey sandy flagstone, apparently hardened near the top. *c.* Fine-grained granular felstone and courses of clay-stone, some of which are used as oven-stone. *d.* Altered flags, having a conchoidal fracture, in parts almost lydian-stone, with crystals of iron-pyrites. *e.* Grey felspar rock, the laminæ of deposit marked by ferruginous streaks, probably due to the decomposition of some other mineral. *f.* Black shivery shale, containing a few concretions of argillaceous limestone, with veins of calcareous spar. One of these, which fell under my notice, was a septarium, two or three feet in diameter, containing many impressions of *Graptolites.* This band of black shale was foolishly excavated to some distance in search of *coal* (!) on

the strike of the beds, by the same individuals who sought for lead-ore. *g*. Hard, thick-bedded, porphyritic felstone. *h*. Flagstone, with *Ogygia Buchii*, and much iron-pyrites indurated by contact with the igneous rock. *i*. Grey porphyritic clay-stone. *j*. Black schist, with some hard stone bands, in parts pyritous. *k*. Slaty porphyritic felstone. *l*. Black shale, with stone bands and concretions of argillaceous limestone. *m*. Thin band of decomposed granular felstone, weathering to a rusty colour, and looking like a coarse sandy oolite. *n*. Black pyritous schists, much contorted near the mouth of the gallery.

Thus, in a thickness of only 350 feet across the beds, this detailed section of the order exhibited in one of the original typical Silurian tracts, displays felstones and porphyritic rocks, occasionally both crystalline and amygdaloidal, with clay-stone, granular felspar, &c. These materials alternate, six or seven times, with finely laminated flagstones and black schists, containing Graptolites and Ogygia Buchii (Pl. III. f. 1). In truth, therefore, this little section exhibits an epitome of the structure of vast tracts in North Wales.

The intrusive rocks which have broken through and diversified these tracts of Shropshire, Montgomeryshire, and Radnorshire, now under consideration, whether large masses or mere dykes that traverse the contiguous strata, were most of them laid down in my map of the Silurian region, and have since been more accurately defined by the Government Surveyors (see Sheets 60 & 61). They are chiefly coarse-grained greenstones and felstones, some of the former passing into basalt. In many cases the shale or schist in contact with the eruptive rock has been converted into porcellanite, with surfaces smoother than the finest lithographic stone. These altered shales are, in fact, the 'Brand-Erde,' or burnt-earth, of the Germans * (Sil. Syst. p. 275).

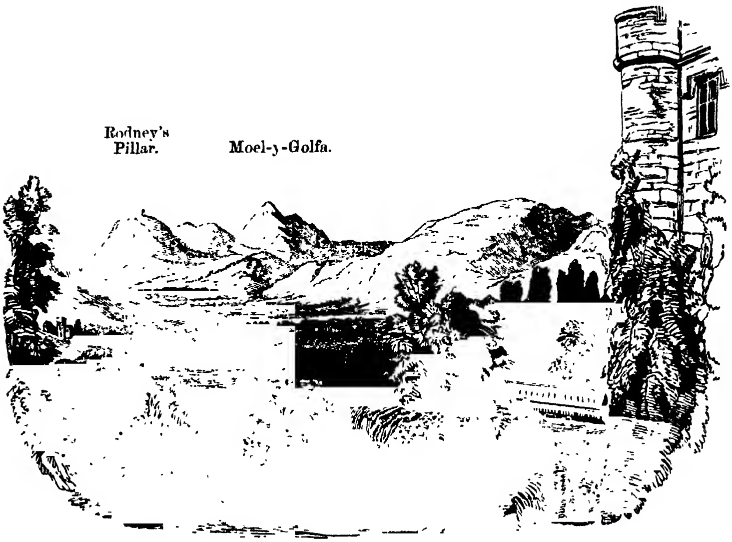
The Breidden Hills, including the picturesque Moel-y-Golfa, on the right bank of the Severn, near Welsh Pool, also exhibit similar illustrations, both of cotemporaneously bedded ashes and of eruptive or intrusive igneous rocks, which have broken out along the same line at different periods †.

The annexed drawing, taken from the terrace of Powis Castle, shows these hills in the distance to the north-east. They mark a line of eruption that separates the Lower Silurian rocks, on the left hand, from the Upper Silurian of the Long Mountain on the right. Now, it has been demonstrated that along this line of eruption, ranging from S.W. to N.E., some volcanic dejections were spread out on the sea-bottom during the formation of the Lower Silurian strata, and that other eruptions and dislocations afterwards took place along it, heaving the strata into highly inclined positions, like those on which Powis Castle stands. It further appears that on the edges of these Silurian and volcanic rocks Carboniferous deposits were afterwards accumulated, and that again, after all these and other formations, including the New Red Sandstone and Lias, were

* In England, curious actual proofs of this conversion occur in the South Staffordshire coal-field, near the town of Dudley, where the long-continued combustion of subterranean coal in abandoned mines has converted the associated shale and sandstones into burnt-earths, or porcellanites of divers colours, some of them resembling the riband-jasper of mineralogists.

† See detailed descriptions, Silurian System, p. 287 *et seq*.

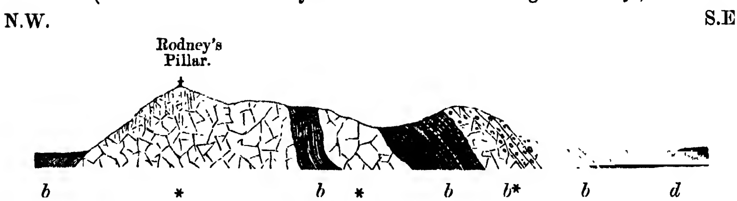
completed, still more recent eruptions occurred along this same line of fissure *, as indicated by igneous dykes which traverse those Secondary formations to the north of Shrewsbury.



VIEW OF THE BREIDDEN HILLS NEAR WELSH POOL, FROM POWIS CASTLE.
(From a Drawing by Lady Murchison, Sil. Syst. p. 302.)

The shortest method of explaining to the reader the structure of the Breidden Hills is to exhibit this small diagram. It represents a mass of

SECTION ACROSS THE BREIDDEN HILLS.
(Taken from a Section by Mr. Aveline of the Geological Survey.)



b. Lower Silurian slaty rocks. *b**. Cotemporaneous volcanic breccia. *d*. Wenlock shale, or base of the Upper Silurian. * Eruptive rocks.

porphyritic and amygdaloidal greenstone, which in its protrusion has carried up included portions of slaty rocks, and has thrown off pebble-beds and Upper Silurian rocks to the S.E., and Lower Silurian to the N.W.

One of the igneous rocks most easily examined, on this line of habitual outburst in ancient periods, is the large basaltiform mass at Welsh Pool,

* For the proofs of this see Sil. Syst. p. 299 *et seq.*

which cuts, as a dyke, through the Lower Silurian strata and has much altered them. At a little distance, however, from the trap-rock, those beds contain organic remains, some of them having particularly the Trinucleus concentricus or T. Caractaci (see Pl. IV. f. 2–5).

This prismatic igneous rock is largely quarried as a building-stone, like that of the Whittery Quarries. It is remarkable in having its light-green felspathic matrix abundantly speckled with minute kernels of calcareous spar, which being mixed with the finely aggregated felspar renders the rock a sectile and valuable freestone.

Eruptive greenstones, as well as hypersthene rock, are seen to cut through Silurian strata near Old Radnor (Sil. Syst. p. 318); but as they are associated with strata of younger date than those we are now considering, they will be more appropriately mentioned in another chapter.

On the flanks of the Carneddau Hills, between Llandrindod and Builth, there are irregular masses of igneous rock which have broken through and highly altered the Llandeilo Flags. Beautiful examples of this are seen on the banks and in the bed of the Wye, west of Builth. (See Sil. Syst. p. 332 *et seq.*)

On this occasion one diagram only is selected from the plates of my large work, to show, first, how the strata of the Llandeilo formation alternate with bedded igneous rocks, *b**, and, next, how they have been altered in contact with eruptive masses, *. It is in these black and hardened schists, along the lines of contact, that films of anthracite were found, which led credulous farmers to search for coal †.

SECTION ACROSS THE GELLI HILLS.

(From Sil. Syst. pl. 33. f. 5.)

b. Llandeilo Flags. *b**. Llandeilo Flags with interpolated cotemporaneous felspathic ashes, &c. * Eruptive rocks.

Another frequent result, in this district, of the intrusion of the igneous rock into the schists is the production of much sulphuret of iron, the decomposition of which mineralizes the various waters at Llandegley,

† A full exposure of this folly was given in the 'Silurian System,' p. 328, with this diagram, representing an actual search after coal (!) at a spot called Tin-y-Coed, thus:—

b, Llandeilo schists traversed by a gallery, *c*, until the eruptive trap-rock, *, was reached, where the *coal*-enterprise was necessarily stopped.

Llandrindod, Builth, Llanwrtyd, &c. that gush out around or near this volcanized tract.

In North Wales, some of the finest examples of the stratified and cotemporaneous beds of felspathic ash or volcanic grit are exhibited in the environs of Ffestiniog. There the interval between the green and grey schists, of the age of the Lingula-flags of Tremadoc, and certain overlying black roofing-slates is occupied by syenite, satiny schists, and volcanic grits, the last being partly coarse conglomerates. To the west of Tan-y-bwlch, these beds assume the form of ashes, which are there as finely levigated as the materials of many schists. They are associated and alternate with hard grit, penetrated by large branching veins of white quartz.

Occasionally this felspathic ash is separated into thick beds formed of slightly inclined laminæ of deposit, and is traversed by numerous highly inclined lines of slaty cleavage, from which the associated coarse grits are exempt.

An adequate acquaintance with such features can be attained only by traversing those mountains with the remarkable illustrations of the Geological Survey in hand†. In the area of a few square miles, the geologist there meets with numerous grand alternations of interstratified volcanic tuffs and conglomerates, mostly felspathic, but sometimes sandy and calcareous, which have been pierced by eruptive igneous matter, whether syenite, felstone, or greenstone, here and there porphyritic‡. It is, indeed, sometimes most difficult to separate the cotemporaneous igneous rocks ('porphyries' of Sedgwick) from the subsequently intruded masses.

Then, again, let the student have with him the minutely worked maps of these districts, and, observing the faults or fractures as delineated on them by the great number of white lines, he may form some idea of the consummate skill and labour by which such results have been obtained.

This brief sketch of the igneous operations which were the accompaniments of the Lower Silurian sediments cannot, indeed, be better terminated than by exhibiting two woodcuts, reduced from the large Sections of the Survey, which record the labours of Ramsay and Selwyn in North Wales. The first of these diagrams (p. 83) represents the relations of the different rocks composing the mountain of Cader Idris, near Dolgelly.

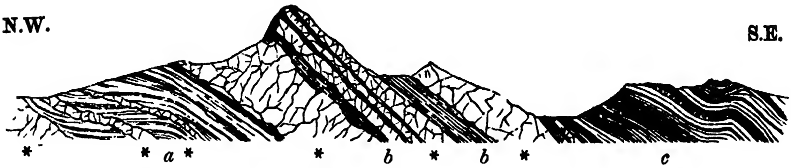
The lowest strata here indicated, *a*, are slaty schists, containing a few Lingulæ; they have been traversed by porphyry, *, and towards their summit contain some layers of felspathic ashes. Then follow grand masses

† The repeated alternations of these volcanic rocks with the schists and slates of North Wales can be best understood by reference to the maps and sections prepared by Ramsay and Selwyn. See Sheets 75 and 78 of the Geological Survey Map, and the illustrative Sections of the same on the six-inch scale. In the small Map attached to this work, and which, as before explained, is simply a reduction of that of the Government Surveyors, numberless details are necessarily omitted. These have now been thoroughly illustrated in the new work of the Survey, by Ramsay, 'The Geology of North Wales.'

‡ A fine example of this succession to the north of Ffestiniog was pointed out to M. de Verneuil and myself by Professor Ramsay in 1851, the real merits of whose labours have recently been made known in an admirable Memoir of the Geological Survey. It is, indeed, a perfect model of what a work ought to be which professes to describe the true structure of a complicated region. The fossil remains are well described by Mr. Salter.

of porphyry and greenstone, *, which alternate with Lower Silurian slates, probably of the Llandeilo age, *b*, and some accompanying ash-beds;

Cader Idris.



a. Upper part of the Lingula-schists, with porphyry. * Grand masses of porphyry and other igneous rocks, with courses of hard slaty Lower Silurian schists, *b.* *c.* Lower Silurian, assuming its ordinary character of shale when removed from the igneous rocks.

whilst the overlying slates and schists, *c*, are Lower Silurian rocks, which resume their ordinary characters when removed from the igneous foci of which Cader Idris was one great centre of action. Thus we see, in examining this mountain, that the crystalline and slaty strata on its flanks, *b*, are succeeded by other masses, *c*, which, in proportion as they recede from the igneous rocks, partake more of the character of 'mudstone.' This character prevails, indeed, wherever the strata are unaltered, from the base of the Silurian system to the very youngest of its beds.

The following section (p. 84) illustrates the structure of Snowdon, and shows to what an extent the sediments constituting the highest mountain in England and Wales have been modified. Independently of the slaty cleavage by which large portions, and particularly its western flanks, have been impressed, as seen in the fine lines which cut across the beds, under the word 'y-Tryfan,' the student will perceive that rocks inferior to any which are sketched in the foregoing section of Cader Idris are here represented†.

The strata, *c*, which constitute the lower portion of Snowdon, and repose upon the older slates and Lingula-flags, *b*, consist of dark bluish-grey slaty schists, representing the inferior part of the Llandeilo formation. In them, however, no clear fossil evidences have been detected. They are traversed by masses of eruptive rock (*), which, whether consisting of porphyry and greenstone or of compact felspar (felstone) have been described by Sedgwick, and their relations have been completely defined by Ramsay. In following, however, these same beds a few miles, to the environs of Ffestiniog, we meet with the fossils of the lower member of

† Professor Ramsay's observations on these igneous phenomena in North Wales, are elaborated with great ability and precision, in his recent publication in the Memoirs of the Geological Survey, in Chapters xvii. & xviii., which are specially recommended to the attention of geologists. He assigns good grounds for the belief that, although some of the intruding bosses and dykes of porphyry, syenite, and greenstone were posterior to the sedimentary felspathic ashes and other volcanic sheets which they traverse, others probably represent the deep-seated portions of the volcanic centres whence ejections and flows of felspathic lava took place during the Lower Silurian epoch. He also infers that all those igneous rocks were formed during the older Silurian period, commencing at the close of the deposition of the Lingula-beds. He establishes this important inference by pointing out that the intruded masses have all been subjected to subsequent forces which bent, contorted, and fractured those ancient accumulations. Hence both the interstratified and the intrusive igneous rocks pertain to the same great Lower Silurian epoch. (See also Quart. Journ. Geol. Soc. vol. ix. p. 170, 1853.)

the Llandeilo formation already indicated, and thus the age of the whole mass is established. In the next overlying accumulations, *d*, we already find many Caradoc fossils, although the original beds alternate rapidly with volcanic dejections of felspathic and other materials.

SECTION ACROSS THE SNOWDON RANGE. (From 'Horizontal Section No. 28,' Geological Survey.)

a. Cambrian grey and purple grits and slates, much dislocated and supporting Lingula-flags. *b*. Lingula-flags, faulted. *c*. Slates (Llandeilo), dark-grey, traversed by eruptive dykes, * (the bedding almost obliterated), followed by *d*, bluish-grey and brownish sandstone and slate ('Lower Caradoc beds) with felspathic ashes and volcanic grit, *d**. *e*. Upper part of the Caradoc (or Bala) beds, fossiliferous, with calcareous and felspathic ashes.

For a graphic delineation of these grand igneous phenomena of North Wales, I refer the reader to Prof. Ramsay's description of the enormous outpourings and accumulations of volcanic materials in Merioneth and the neighbouring districts, where he finds that 'ash-beds' are certainly underlain by porphyritic rocks over an area of at least 60 square miles, and were once probably overlain by an equally wide sheet of felspathic lava,—the igneous rocks of Snowdon itself being estimated to have a thickness of 3100 feet, without the intercalated beds of fossiliferous grits and slates. ('Geology of North Wales,' p. 133.)

Truly grand as are these igneous features of North Wales (and similar phenomena, though on a less scale, occur in South Wales—Pembrokeshire), they are, I repeat, precisely of the same class as those of the western hills of Shropshire, described (pp. 65, 67) as the true Lower Silurian types, and the age of whose volcanic eruptions was established by the associated organic remains. In like manner, we now know, through their imbedded fossils, that the slaty and arenaceous masses, with their beds of igneous deposits, constituting the summit of Snowdon were formed at the very same time with the shelly sandstones of the humbler hills on the eastern flank of Caer Caradoc.

CHAPTER V.

LLANDOVERY ROCKS (TRANSITION FROM LOWER TO UPPER SILURIAN).

THIS FORMATION SHOWN TO BE OF INTERMEDIATE CHARACTER, CONTAINING BOTH LOWER AND UPPER SILURIAN FOSSILS, WITH SOME PECULIAR TYPES.—ASCENDING ORDER OF THE WHOLE GROUP NEAR LLANDOVERY IN SOUTH WALES, WHERE MOST DEVELOPED.—THE UPPER PORTION ALONE EXHIBITED IN RADNORSHIRE, SHROPSHIRE, HEREFORDSHIRE, THE MALVERN HILLS, MAY HILL, TORTWORTH, THE LICKEY HILLS, ETC.—TARANNON SHALES, OR BASE OF THE UPPER SILURIAN IN NORTH WALES.

In my earlier publications, the whole group of strata to which attention is now invited was placed at the summit of the Lower Silurian rocks. The progressive researches and labours of my cotemporaries, however, have for some time led me to admit that, whilst the lower and larger portion of this formation is related, through numerous organic remains, to the inferior half of the system, the higher member, though also containing some of the lower types, is, by many of its fossils, more naturally connected with the Upper Silurian *. At the same time, the formation is eminently characterized throughout by certain Pentameri peculiar to it, which are not known either in the subjacent or superjacent deposits, and also by some species of other shells which never rise into the Wenlock (or true Upper Silurian) rocks. A short chapter is therefore devoted to the consideration of this group, showing its intermediate character and varied development in different localities.

Though not recognizable in the northern or central parts of the Silurian region, the inferior member of the formation is fully exposed in extensive tracts of South Wales to the north and west of Llandeilo, particularly near Llandovery, where it was formerly described in detail (Sil. Syst. p. 351). Let us first, then, consider the nature and contents of these rocks as seen in ascending order in the last-mentioned tract, where both their members are exposed, and afterwards treat of them in certain districts where the lower member of the group is wanting and the uppermost subdivision alone is visible.

In the first edition of this work, all these rocks were termed 'Upper Caradoc;' but that term was set aside in the last edition. The local name of 'Llandovery Rocks' was then taken, from the district where clear physical relations are seen of the transition from the Caradoc formation beneath,

* This last feature was first pointed out by Professor Sedgwick and Professor M'Coy in their memoir on the May Hill Sandstone (Phil. Mag ser. 4. vol. viii. 1854, p. 301).

up into the lower member of these deposits, and from the latter into the upper band of the formation. The table of colours attached to the Map, and the accompanying brackets, explain the nature of this link; and the geologist who may examine the various tracts of country described in these pages will readily understand this classification.

Reverting to the natural section where the flags of Llandeilo (p. 73), to the north of the town of that name, are overlain by the equivalents of the Caradoc formation, it has been observed that there the strata of the latter graduate upwards into coarser sandstones, occasionally conglomerates, in which some Pentameri have been found. These last-mentioned strata, though containing few fossils, extend, as already mentioned, over considerable tracts of South and North Wales, where they really form the summit of the Lower Silurian rocks.

On the left bank of the Towy, and particularly in all the tract extending from the River Sowdde to Noeth Grüg, north of Llandovery, these sandstones and shales, with a conglomerate at their base, and also resting on Caradoc rocks, prevail in a range of hills whence many characteristic fossils, published in the 'Silurian System,' were procured *. It was formerly stated that in the environs of Llandovery this sandstone had not the durability and firmness of the Caradoc Sandstone of Shropshire, and was not so easily separable from those Upper Silurian rocks from beneath which it emerged in the wooded hills near that town. The formation, however, was shown to be loaded with many fossils of true Lower Silurian character, derived from Rhiwfelig, Blaen-y-cwm, Cefn Rhyddan, and Goleugoed, the last-mentioned locality, whence the Llandovery building-stone is extracted, having afforded most of the species.

The following fossils, figured in the 'Silurian System,' are repeated from that work in Plates VIII., IX., X., XI.: viz., Orthoceras bisiphonatum; O. approximatum; Lituites undosus; L. cornu-arietis; Pleurotomaria Pryceæ; P. angulata; Holopella cancellata; Rhynchonella pusilla; R. neglecta; R. tripartita; Orthis lata (including O. protensa); O. calligramma; O. Actoniæ; O. elegantula; Atrypa crassa; A. reticularis; Pentamerus lens; P. globosus; P. undatus; P. oblongus, or lævis; Strophomena compressa; Leptæna sericea, &c. &c.†

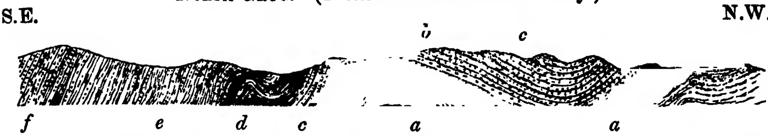
In following these rocks to the north-east, by Llandovery, through the elevated moory grounds of Mwmfre, they are seen to become more quartzose, and to rise up into the bare and stony hills of Noeth Grüg and Cefn-y-garreg about 1500 feet above the sea, where the whole formation is admirably exposed, as in this diagram ‡.

* The collections were chiefly made by my respected friend the late Mr. Williams, Surgeon, of Llandovery, and his son, now the Rev. Stewart Williams.

† Several names of fossils given in the 'Silurian System,' p. 351 &c., are here omitted, as more perfect specimens have shown that those forms belong to some of the species here named. The names of some genera have also been changed; but the types remain the same.

‡ I revisited this locality since the first edition of this work, in company with Earl Ducie, Prof. Ramsay, and Mr. Aveline. The latter furnished me with a section more accurate than any one previously published, although it does not differ essentially from the original section given in the 'Silurian System.'

NOETH GRÜG. (From the Government Survey.)



a. Schists, &c., representing the Caradoc formation. *b.* Lower Llandovery rocks (Llandovery Sandstone). *c.* Upper Llandovery rocks: equivalent of the May Hill Sandstone. *d.* Tarannon Shale, or 'pale slate' (of which hereafter). *e.* Wenlock and other Upper Silurian strata, without subdividing limestones. *f.* Base of Old Red Sandstone. (Compare with Section, Sil. Syst. pl. 34. f. 3.)

Wild and uninhabited, this small tract is truly remarkable in being the only one in England and Wales wherein the lower and upper zones of the Llandovery rocks have as yet been observed in a united mass, and with clear relations to the inferior and superior strata. In the last chapter a succession from the Caradoc formation into the lower member of this group was, indeed, indicated as occurring over large districts of the west of Carmarthen and Cardigan. But there the upper member of the Llandovery rocks seems to be wanting, and no overlying Upper Silurian strata are contiguous, as in this district. In the bare and rocky undulations around Noeth Grüg, no unconformity is observable between the underlying beds, or the representative of the Caradoc formation, and the Llandovery strata surmounting them, which are laden with Pentameri and other fossils of the group under review. Nor is any discordance visible either between the Lower and Upper Llandovery rocks, or between the latter and the overlying Upper Silurian strata, as well as the Old Red Sandstone. What then is the age and equivalent of the lower and larger portion of the hard gritty sandstone (*b*)? If mineral aspect be considered, this rock would certainly be ranked as one of high antiquity; for the softer and more argillaceous sandstone and building-stone of Llandovery has in the short intervening distance become a hard intractable grit, traversed by planes of slaty cleavage, as shown in the white lines of the drawing.

Again, if the fossils of the lower beds of these sandstones be appealed to, we find in them, either at this or other localities, the following unquestionable Lower Silurian types:—Illænus Bowmanni, Salter; Lichas laxatus, M'Coy; Murchisonia simplex, id.; Orthis insularis, Eichwald; O. calligramma, Pl. V. f. 9; O. Actoniæ, ib. f. 11; Strophomena bipartita, Salter; Leptæna sericea, Pl. V. f. 14; Cyclonema crebristria, M'Coy; Lituites cornu-arietis, Pl. XI. f. 1; Orthoceras bilineatum, Hall. (See also woodcuts in Chapter IX.)

In addition to these forms, none of which rise higher in the series than the zone under consideration, the following species, which are also of Lower Silurian date, range upwards through all the Llandovery rocks into undoubted Wenlock or Upper Silurian. These are: Atrypa marginalis, Pl. IX. f. 2; Orthis elegantula, f. 19; O. occidentalis, Hall; Strophomena antiquata, Pl. XX. f. 18; S. pecten, Dalm.; Conularia Sowerbyi (quadrisulcata, Sil. Syst.), Pl. XXV. f. 10; Bellerophon dilatatus, f. 6; Orthoceras ibex, Pl. XXIX. f. 3. (See Plates VIII. to XI., and woodcuts in Chapters VIII. & IX.)

There are other fossils which occur in both the Lower and Upper Llandovery rocks, such as Leptæna sericea, Orthis reversa, Rhynchonella furcata, R. angustifrons, Raphistoma lenticularis, Holopella cancellata, Petraia subduplicata, and P. elongata. The chief character, however, which unites the lower and upper members of this formation, besides the community of these and other species, is the great abundance of Pentamerus, Atrypa, and Petraia,—and the absence of all, or nearly all the characteristic Trilobites of the subjacent deposits.

The upper member of the group, *c*, as seen on the summits and slopes of the hills of Noeth Grüg and Cefn-y-garreg, has always seemed to me (even in my last close reexamination in 1856) to form the regular and conformable capping of the lower strata, *b*. In it we not only find the continuance of the same lithological character and colour of the hard, gritty stone, but also the same distinguishing fossils, the Pentameri, of which Pentamerus oblongus becomes much more abundant and characteristic, though still accompanied by P. undatus and P. lens (see Pl. VIII.). Figures of the other fossils of this zone, including the Atrypa hemisphærica, A. reticularis, Bellerophon trilobatus, Encrinurus punctatus, and Petraia subduplicata, will presently be given in describing the range of these Upper Llandovery rocks through Shropshire and other tracts, where these types are associated with Upper Silurian fossils.

Upper Llandovery Rocks in Radnorshire, Shropshire, Herefordshire, the Malverns, &c.—In quitting the typical Llandovery tract, and in proceeding to the N. and E., or to the S.W., the Geologists of the Survey have everywhere observed a marked absence of the lower member of the Llandovery rocks, and have ascertained that the upper zone with Pentamerus oblongus is alone present, and forms the natural base of the Upper Silurian rocks.

Thus, in Radnorshire, this upper zone is represented by a thin course or two of sandstone or conglomerate, occasionally resting, as near Builth, in striking unconformability on the upturned edges of the Llandeilo flags. That tract, it will be remembered, like the district of Shelve and Corndon in Shropshire, is replete with igneous rocks; and, in both, the Llandeilo formation appears to have been raised from beneath the waters, and not to have been depressed or again subjected to any marine action during the whole period when the Caradoc formation was accumulating. Such relations are strikingly exhibited in the diagrams already given at p. 59.

In tracing the relations of the Caradoc sandstones of Shropshire to the overlying shale and limestone of the Wenlock Edge, I was formerly led to believe in the existence of an unbroken ascending series. This appeared to be the case on the banks of the Onny, where that river flows from Horderley on the N.W. to Wistanstow on the S.E. I then saw that the lower beds of the Caradoc formation were highly inclined in the proximity of the igneous rocks of Caer Caradoc, but that the inclination decreased gradually to the east, so that the flagstones of Cheney Longville, which were described in the last Chapter, seemed to pass with apparent conformity under those beds of shale and limestone which contain Pentamerus oblongus. Now, as I had found this same characteristic fossil in strata of South Wales which graduate downwards (as already shown) into rocks with

RELATIONS OF THE UPPER LLANDOVERY ROCKS TO THE INFERIOR AND SUPERIOR DEPOSITS, BETWEEN THE LONGMYND ON THE N.W. AND THE FOOT OF WENLOCK EDGE ON THE S.E. (From 'Horizontal Section 33,' Geological Survey.)

a, a. Longmynd or Cambrian rocks. *c.* Caradoc formation. *e.* Upper Llandovery rocks. *f.* Wenlock shale.

Lower Silurian forms, and had never detected it in the overlying Wenlock shale, and, further, as in the greater part of the Silurian territory the strata which contain it are coarse grits and sandstones resembling the inferior rocks, but wholly unlike the superior argillaceous formations of Shropshire and Herefordshire, I naturally classed the rock with the Lower Silurian.

Many years elapsed, and even the Geological Surveyors also examined and mapped the district under consideration without perceiving the break; but it was detected in 1853 by the researches of Messrs. Aveline and Salter (Quart. Journ. Geol. Soc. vol. x. p. 62). These gentlemen observed a want of conformity between the great mass of the so-called Caradoc sandstone beneath and the rocks with Pentamerus above, the latter being perfectly conformable to the Wenlock shale. The amount of unconformity, as seen in this woodcut, which is taken from a published section of the Government Survey, is greater than that which can be detected on the line near Wistanstow, on which the succession was originally noted by myself *.

This diagram exhibits not only the Upper Llandovery rock reposing in one place upon the truncated edges of the Cambrian or Longmynd rocks, *a*, and in another place transgressive on the true Caradoc, *c*, but is further highly expressive of the powerful fractures or faults by which the typical region has been affected at periods long subsequent to all those movements of the subsoil which produced the unconformable deposition of these strata.

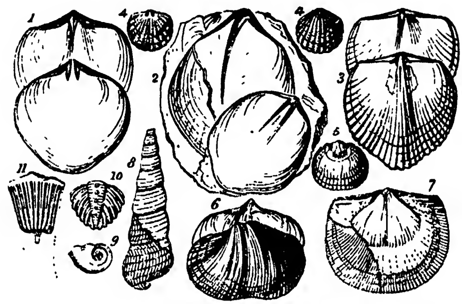
When this country was examined by me in 1832–3–4, it was, indeed, considered that the powerful outbursts of igneous matter, seen in the contiguous eruptive

* The amount of this discordance on the Onny is so slight, and the banks of the river at the point of junction are so overhanging, that the slightly transgressive arrangement of the strata can only with great difficulty be ascertained, and that when the river is very low; at other times the river must be waded to see the break.

ridge of Caer Caradoc, might well account for all such partial dislocations; and as the uppermost of the shelly sandstones at Cheney Longville clearly dipped under the Pentamerus zone or Hollies limestone (Upper Llandovery rock), and this last passed under the Wenlock shale, the general order of superposition, notwithstanding the adjacent disturbances, could not be doubted. See the preceding general woodcut, page 64.

The fossils which most characterize this member of the deposit in Shropshire, as elsewhere, are Pentameri, particularly P. oblongus and P. lens, with Atrypa hemisphærica, Rhynchonella decemplicata, and Strophomena compressa. With these, however, there are other species, some of which occur in the Lower and many others in the Upper Silurian rocks. Among

UPPER LLANDOVERY FOSSILS (15).



1. Pentamerus lens. 2. P. oblongus. 3. P. liratus, Sow. 4. Atrypa hemisphærica. 5. A. reticularis. 6. Pentamerus undatus. 7. Strophomena compressa. 8. Holopella cancellata. 9. Bellerophon trilobatus. 10. Encrinurus punctatus. 11. Petraia subduplicata, M'Coy.

the former are some of the species already enumerated, viz. Leptæna sericea, Orthis calligramma, O. biforata, Cyclonema crebristria, and all the species above mentioned (p. 87) which range from the Lower into the Upper Silurian rocks. The species common to this zone and the overlying formations are Phacops Stokesii, Atrypa reticularis, Pterinea retroflexa, Bellerophon trilobatus, B. expansus, and others.

The woodcut, Foss. 15, exhibits those fossils only which are truly typical of the Llandovery rocks. Some of these forms, however, are so abundant in the Lower Silurian as well as in this zone, and so rare in the Wenlock formation or base of the Upper Silurian, that they still give a distinct impress to the deposit.

In Shropshire, this zone of Pentamerus rock varies much in dimensions. When followed to the N.E. from the banks of the Onny, where it is a thin calcareous course only, it so swells out in the parishes of Church Preen and Kenley, that a considerable thickness of sandstone and conglomerate is there interposed between the shelly sandstone of Caer Caradoc and this Upper Llandovery limestone. Both those villages, as described in the 'Silurian System,' stand upon coarse grits with white quartz pebbles, in

parts almost a conglomerate, the beds rising at a low angle from beneath the Hollies or Pentamerus limestone and the overlying Wenlock shale, to both of which they are conformable. The chief fossil in this coarse grit and conglomerate is Rhynchonella decemplicata (Pl. IX. f. 15). These rocks also range up to the south-eastern flank of the Wrekin, and dip with the Pentamerus limestone under the 'Die earth,' or Wenlock shale, of Buildwas and the gorge of the Severn.

On the south flank of the Longmynd, this zone, whether in the form of a pebbly conglomerate or of an impure limestone, both charged with Pentamerus oblongus, reposes at a low angle of inclination on the ancient rock, as thus represented in my old work.

(From Sil. Syst. pl. 32. f. 4.)

At the spot to which this diagram refers, copper veins, *v*, are seen to penetrate both the subjacent Longmynd rock, *a*, and the overlapping Pentamerus rock, *e*,—the last being overlain by Wenlock shale, *f*.

In another part of Shropshire the rock is seen to protrude along a line of fault as an isolated patch through the Wenlock shale of Brampton Bryan Park, and is again visible further to the S.W. at two points in Radnorshire,—the one in a dome to the south of the town of Presteign, the other on the western slopes of the hill of Old Radnor. (See Map.) In these examples it is a quartzose, pebbly conglomerate, passing into a hard, coarse grit (Corton), in which casts of Pentamerus oblongus and other fossils occur, such as Atrypa hemisphærica, Petraia elongata, and P. bina. Along this line it is also obviously the lowest bed brought up in domes and arches by the line of igneous eruption, along which the hypersthenic and felspathic rocks of Stanner, Hanter, and Ousel have been evolved. These outbursts have so altered the contiguous sandstones, schists, and grits (just as around the Wrekin and Caer Caradoc), that in Old Radnor Hill and Yat Hill it is difficult to determine which parts of the masses are metamorphosed rocks resulting from the effect of volcanic eruption, and which have really been in a molten state. The diagrams illustrating this phenomenon, including the metamorphosis of the limestone of Nash Scar, will be given in the Sixth Chapter, which treats of the Wenlock formation.

In that district of Radnorshire, the Upper Llandovery rock is a siliceous grit and conglomerate, and is at once conformably surmounted by shale and limestone, which, from their fossils, are grouped as the lower member of the Wenlock formation of the Upper Silurian rocks, or Woolhope limestone, as will be hereafter described.

Again, on the western flank of the Malvern Hills we meet with sandstone and conglomerate characterized by the above-mentioned Pentameri. As these rocks have there, according to Professor Phillips, a thickness of 600 feet, and have peculiar relations to the rocks on which they repose, as

well as to those under which they dip, a few pages may be instructively devoted to a sketch of the leading features of that striking ridge of hills.

Malvern Hills.—The picturesque tract above referred to, detached from the main region over which rocks of Silurian age are continuously extended, is chiefly composed of the undulating grounds which lie upon the western flank of the Malvern Hills. The accompanying vignette represents the

North Hill. Worcester Beacon. Hereford Beacon.

VIEW OF THE MALVERN HILLS FROM THE WEST.
(From a sketch by Lady Murchison, Sil. Syst. p. 409.)

Herefordshire Beacon on the right hand, followed by the Worcestershire Beacon and the North Hill in the distance, as seen from the undulating grounds composed of Upper Silurian rocks which occupy the western flank of the ridge, the highest parts of which are exclusively composed of crystalline rock, both eruptive and metamorphic *.

Though occupying a much narrower zone than in the typical tract of Shropshire, the Silurian rocks constitute an almost continuous band, from the northern end of the Abberley Hills to the southern extremity of the Malvern Hills, a distance of about twenty-four miles. Throughout this space the beds strike, on the whole, from north to south, and dip rapidly to the west, by which they pass under the Old Red Sandstone of Herefordshire †. In the northernmost part of this line of elevation, or the Abberley Hills, no rock of truly eruptive character is seen except at one spot, west of Martley, where, many years ago, I detected a small boss of syenite, identical in character with the chief eruptive rock which protrudes in large masses on the summits and slopes of the Malvern Hills.

That crystalline ridge, chiefly of igneous and metamorphic origin, was

* Since the last edition of this work, the Malvern ridge has been traversed by the Worcester and Hereford Railroad; and a section thereof, on a large scale, was made by Mr. Allan Lambert. A description of the strata passed through, between Malvern Wells and Ledbury, illustrated by a reduced copy of that section, is given by Mr. Lambert and the Rev. W. S. Symonds, in the Journal of the Geological Society, vol. xvii. p. 154 &c. The relative position of the several igneous and schistose rocks of the Malvern Hills, succeeded on that parallel by the Upper Llandovery and the whole series of the Wenlock and Ludlow rocks, is there faithfully recorded; and an interesting exposure of the Passage-beds from the Ludlow rocks into the Old Red Sandstone, at Ledbury, is described both in that memoir and in vol. xvi. p. 194, of the Geological Society's Journal.

† On the east all these rocks are flanked by the New Red Sandstone, the divisions of which have been laid down in the Sheets 43 & 55 of the Geological Survey Map. See also the memoirs, by the late Hugh Strickland, Phil. Mag. 4th Ser. vol. ii. p. 358; and by the Rev. W. S. Symonds, Journ. Geol. Soc. vol. xi. p. 450, vol. xvii. p. — ; Edin. New Phil. Journ. vol. v. p. 257.

well described by Mr. Leonard Horner in the infancy of English geology. The prevailing rocks are varieties of syenite, consisting of quartz, felspar, and hornblende, and occasionally, where the last-mentioned mineral is absent, presenting the appearance of a true granite. Of the other minerals, epidote is most disseminated. Again, compact felspar-rock or felstone is abundant, and passages from it into syenite and greenstone are not unfrequent. These amorphous rocks have evidently intruded upon certain stratified deposits which, usually in a highly altered condition, occur in and along the syenitic chain. They consist of chloritic schist, quartzite, and highly twisted micaceous schist, passing into a sort of gneiss.

I have already assigned (p. 14) my reasons for not accepting the ingenious interpretation of Dr. Holl*, that these crystalline rocks are of Laurentian age, and have explained why I consider them to be a metamorphosed mass of the lower portion of the Cambrian deposits, and therefore equivalents of the crystalline (metamorphic) Cambrian rocks of Anglesea and North Wales. In thus differing from Dr. Holl, I am bound to say that his memoir on the Malvern Hills is well worthy of being studied by geologists; for, irrespective of the theory by which the crystalline rocks are referred to the Laurentian age, all the subdivisions of the rocks composing these hills are most instructively indicated,—the mineral characters of the crystalline rocks, as determined by the Rev. J. H. Timins, being described with great skill, some corrections being made in the mapping of faults and strata, and much interesting information brought to bear on the history of the formations and their changes.

It not being within the scope of this volume to describe in detail the former effects of eruptive molten matter in transmuting the character and condition of the sediments through which it bursts forth, I would beg geological students to examine the natural section (p. 95), with the detailed works of Phillips, Symonds, and Holl in hand. According to my view, he will see that, as the strata flanking the ridge on either side approach to its central part, or axis of igneous rocks, they gradually become more hard and brittle, and that, their schistose character gradually ceasing, the beds pass into thick amorphous masses, in which the lines of bedding are lost, and the substance is much altered and fissured by many devious joints with serpentinous coatings. The nucleus or eruptive mass, exposed in extensive quarries in Ragged-stone Hill, near the White-leaved Oak, is compact felspar, passing into syenite; but the northern extensions of this same eruptive ridge, particularly as displayed in the Worcestershire Beacon and North Hill, contain other varieties of the igneous rocks already spoken of†.

It would appear from the close examination made by the Rev. W. S. Symonds and Mr. Allan Lambert, during the making of the tunnel at

* See his memoir, Quart. Journ. Geol. Soc. vol. xxi. p. 72 &c.

† It was gratifying to me, in a visit with Professor Ramsay, to observe that this minute point of the syenitic axis, which I first observed in 1852, was still visible in 1858 in the bottom of the quarries; for doubtless it may now be hidden by débris, and subsequent observers might be sceptical.

Malvern Wells, on the line of the Worcester and Hereford Railway, that the nucleus of the hills there, as at the White-leaved Oak, consists of igneous rocks, traversing the old syenitic gneiss, and really constituting the centre of the Malvern range. The eruptive rock, however, must have cooled and hardened long before the period of the deposition of the Upper Llandovery sandstone; for Mr. Symonds mentions that he was astonished to find almost in the centre of the hill two thin bands of that rock, containing characteristic fossils, which had evidently been deposited in a fissure in the syenitic rock when the ridge of the Malverns was submerged beneath the sea of the Upper Llandovery period. (Quart. Journ. Geol. Soc. May 1861.)

The lowest of the unaltered deposits which have been termed Silurian by Professor Phillips and myself is the Hollybush Conglomerate and Sandstone; and these are overlain by certain schists, which are in parts so black as to have given the name of Coal Hill to some hilly arable ground to the west of Keys End Hill (see p. 95).

These lower strata of sandstone and black shale extend from north to south along the slopes of Midsummer Hill, Ragged-stone Hill, and Keys End Hill, or the southern portion of the chain, for a length of upwards of two miles, and have an average width of half a mile from east to west, in which space they are perforated, here and there, by small bosses and dykes of intruded greenstone, as laid down in the Map of the Survey*. Volcanic grits and lavas interstratified with both the Hollybush Sandstone and Black Shales have been carefully described by Dr. Holl.

The Hollybush Sandstone is well displayed in quarries at the 114th milestone on the London-road from Tewkesbury to Ledbury, where the beds dip away from the part of the ridge called Ragged-stone Hill at an angle of 35°. This Hollybush Sandstone, of a light-greenish tint, containing a small portion of mica, and freckled with a few dark stains, had afforded no organic remains, save Fucoids, when the last edition of this work appeared; but since then Dr. Grindrod has discovered in it tubes of Sea-worms, the Trachyderma antiquissimum of Salter, and some other fossils have been found in it by Dr. Holl and Mr. Turner of Pauntley (see p. 45). The beds above the conglomerate are thick, but become flag-like upwards, and pass through sandy shale into overlying black shivery schists.

These schists were first described in the 'Silurian System' (p. 416) as possibly belonging to the Llandeilo group,—that suggestion having been made, in the absence of any known organic remains, from the strata being surmounted by a zone of sandstone with Pentameri, then believed to belong to Caradoc sandstone, followed by a full Upper Silurian series. Subsequently Professor Phillips discovered in these schists the small Trilobite Olenus humilis; and afterwards my lamented friend Mr. Hugh Strickland detected the minute Agnostus pisiformis. The occurrence of these forms,

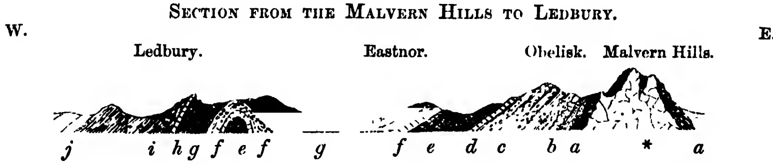
* These protuberances of greenstone were first noticed by Professor Phillips.

so emblematic of one of the lowest zones of Silurian life (see Foss. 7. p. 45), led me to believe that the Hollybush Sandstone and associated schists are the miniature representatives of the Lingula-flags of Wales; and as the Dictyonema (James Hall), the oldest known form of Polyzoon in Britain, has since been found in these beds by the Rev. W. S. Symonds, no doubt of their age can be entertained. In another chapter, and when treating of the Silurian rocks of Norway and Sweden, it will be proved that the relative thickness of deposits is no test whatever of their synchronism, though it is of the time which elapsed during their accumulation. The hundred feet or two of Hollybush Sandstones and black schists now under consideration are, in short, as M. Barrande suggested, the equivalents in time of the Primordial Silurian Zone, or the Lingula-flags of Wales, already described in Chapter III.

The sandstone and black schist which constitute the lowest fossiliferous sediment of this tract are thrown off to the east as well as to the west of the crystalline chain at Midsummer Hill, south of the Hereford Beacon. This is seen in traversing the ridge near its south end, from Chase-end Hill on the east, by the White-leaved Oak, to the hilly arable ground on the west. The Malverns are therefore represented in the following diagram as exhibiting a geological saddle, having one thin and partly metamorphosed flap only on the east side, and several thick flaps on the west, the lower part of one of which only is in an altered condition. Among the older strata visible on the east flank are the same black schists, subordinate to sandy flags, which on the western slope of the ridge of syenite have given to the ground the name of Coal Hill †, and in which the species of Olenus and Agnostus already mentioned have been sparingly detected.

The reader will understand the facts by consulting this little general diagram ‡.

SECTION FROM THE MALVERN HILLS TO LEDBURY.



This woodcut, slightly modified from a coloured section in the 'Silurian System' (pl. 36. f. 8), explains the general order and the undulations on the west side of the Malvern Hills, in the parallel of Midsummer Hill, Eastnor Park, and Ledbury. The eruptive rocks, *, of the Malvern ridge are associated with and flanked by crystalline felstone, schists, and gneissic rocks, *a*. To the west these are followed by the Hollybush Sandstone and the Black Schists with Olenus, *b*. The Upper Llandovery Sandstone and Conglomerate are marked by *c*; their higher portion dips down from the Obelisk Hill of Eastnor, and passes under the Woolhope, or Lower Wenlock limestone, *d*. The latter is followed by the Wenlock shale, *e*, and the Wenlock limestone, *f*; which last, bending under the Lower Ludlow, *g*, reappears in a dome that throws off towards Ledbury the whole of the Ludlow formation, *h i*, after a flexure in Wellington Heath, under the Old Red Sandstone, *j*.

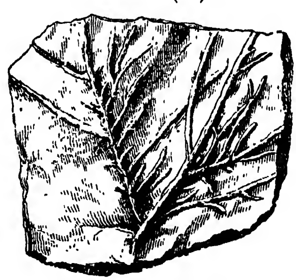
† Absurd trials for coal have been made by ignorant persons in this black Lower Silurian shale *on both sides* of the eruptive axis.

‡ See Sil. Syst. p. 418, and coloured section, pl. 36. f. 8.

The next deposit met with in ascending order in the line of the above section, upon the west flank of the Malverns, consists of grits, conglomerates, and sandstones, occupying, as before said, a thickness of 600 feet, the chief localities being Howler's Heath, Cowley Park, the west of Hereford Beacon, the Wych, &c. The forms usually characteristic of this band of the Upper Llandovery rocks are the Pentameri before noted, Atrypa hemisphærica, Rhynchonella decemplicata, together with some of the Univalve Shells and Corals previously mentioned as occurring at Llandovery. Of the latter, the Petraia subduplicata, M'Coy, is abundant; and Orthis calligramma is not unfrequent. The zone is here specially characterized by a number of bivalve Nucula-like shells; of which Ctenodonta Eastnori and Ct. subæqualis (Pl. X. f. 7, 8) are examples. The last-mentioned species and its associates, Bellerophon trilobatus and Holopella obsoleta (Pl. IX. f. 28), pass upwards, as will be seen in the sequel, to the uppermost Ludlow rock.

One of the shells highly characteristic of the Upper Llandovery rocks in this district is the Lingula crumena, Phill., which was figured by mistake amongst the fossils of the Caradoc formation, 'Siluria,' 1st edition, p. 86 (Foss. 7. f. 5): see above, p. 68 (Foss. 13. f. 5). Even the peculiar Crustacean, Pterygotus, which, as we shall presently see, is eminently an uppermost Silurian form, has its representative here, in fragments which were found south of Eastnor Obelisk by Mr. John Burrow, of Malvern.

FOSSILS (16).



Fucoid in Sandstone: Malvern.

It is also worthy of notice that a perfect cast of a Fucoid was found in a fragment of this rock on the west side of the North Hill by the well-known and zealous botanist Mr. Edwin Lees; and as vegetable remains are rarely found in these deposits, the specimen is here figured*.

These Upper Llandovery rocks, in the form of a dingy purple grit with a superjacent flaggy limestone, range from the End Hill of Malvern to Old Storridge Hill, and are seen for the last time in Ankerdine Hill, the most southern of the Abberley Hills. Throughout its course along the west flank of the Malverns, where it rests upon the eruptive rocks †, and thence to the gorge of the Teme, under Ankerdine Hill, this Llandovery sandstone, with its impure

* There are many specimens of these Fucoids, some of them beautifully preserved, in the collection of Dr. Grindrod at Malvern. It is a question, however, if some of these supposed Fucoids will not turn out to belong to graptolitic or other zoophytes.

† It is worthy of remark that the Llandovery sandstone is altogether obliterated by a fault on the west of the Herefordshire Beacon; while a great upheaval of the purple beds containing Lingula occurs on the flank of the hill immediately behind Mr. Johnson's house on the Ledbury and Malvern highroad. A drawing of the remarkable upheaval of these Llandovery strata may be seen at the Museum of the Malvern Field-Club. Again, the beds which, at the 'Silurian Pass' of Professor Phillips, flank both sides of Swinyard's Hill, along the southern Malverns, belong to the Upper Llandovery strata, and they rest against the old crystalline masses, as may be well seen in the gorge at the bottom of the Gullet Pass.

limestone, constitutes the regular base of all the Upper Silurian rocks which dip away from it to the westward. On its eastern flank, on the contrary, the same rock is brought into abrupt contact (see Map) with the New Red Sandstone by that great longitudinal (north and south) fault which runs along the whole length of the Malvern and Abberley Hills *.

In delineating with great precision the order of the strata as well as their flexures and breaks, Professor Phillips discovered †, on the west side of the Worcestershire Beacon, that one of the local conglomerates (Upper Llandovery, then called 'Caradoc'), charged with several characteristic fossils, contained also pebbles and fragments of the syenite and other eruptive rocks of the Malvern chain, against which the conglomerate rests in a highly inclined position. Hence it was evident that along this line there had been eruptions, which had left a shore or island of hard rock from which the conglomerate in question had been derived. In fact, looking further back, we see that the eruption at the White-leaved Oak and Chase End Hill, to which attention has been called, together with the consequent metamorphism of the Cambrian deposits, took place at a much more remote period, and that there the erupted matter traversed the ancient mass of the ridge before the oldest Silurian strata of the tract, namely the Hollybush Sandstone, had been formed. This sandstone and the Olenus-shales, both belonging to the 'Primordial Zone,' soon die out in their extension northward. Whatever may have been the successive periods of the mutations to which the Malvern ridge has been subjected, it is clear that one considerable elevation of the chain took place after the accumulation of the Upper Landovery rocks, as proved by Prof. Phillips's discovery hereafter noticed. In short, the Malvern ridge had then been left to be acted upon by the sea, so as to furnish materials for the completion of a younger deposit.

The elevation of the Malvern Hills in a solid state, and probably at a later period, together with the folding back of the strata, so as partially to invert the order and place the Upper Llandovery grits over the Wenlock shale, and the latter over the limestone (a phenomenon first pointed out by Mr. Leonard Horner ‡ as due to the uplift of the syenite, the crystalline nucleus of the hills), is of great interest, and such as occurs on a vast scale in the Alps and many other mountain-chains.

* This fault is one of the longest that has been traced in the British Isles. On its western side the various members of the Silurian series above enumerated are seen in some places to be overlain by the Old Red Sandstone. In other localities the Silurian rocks subside, and the Old and New Red are in contact as between the Abberley and Malvern Hills. In its range southwards, the fault is marked by a band of Permian conglomerates; and still further to the south, or towards May Hill, a thin zone of Coal-measures separates the New Red of Gloucester from the Old Red of Hereford. See Sheets 43 & 55 of the Geological Survey Map, in the last of which the relations of other and oblique transverse faults to this great longitudinal fracture are clearly laid down. See also Mr. Hugh Strickland's remarks on this great dislocation, Phil. Mag. 1851, vol. ii. p. 358.

† Memoirs Geol. Survey, vol. ii. p. 66. Miss Phillips made this discovery.

‡ This overthrow of the strata was noticed, and an excellent account of the mineral structure of the Malvern Hills was first given, by Mr. Leonard Horner, in the Geol. Trans., old series, vol. i. p. 281. The nature and succession of the overthrown beds were illustrated in detail by myself, 'Silurian System,' p. 423, and by Professor Phillips, Memoirs Geol. Survey, vol. ii. p. 67 *et seq.*; and, lastly, Symonds, Lambert, and Holl have added much to our knowledge of details and of the probable history of the range, Quart. Journ. Geol. Soc. vols. xvi., xvii. & xxi.

Passing from the consideration of these physical features, other natural appearances on the flank of the Malvern Hills, described by Professor Phillips and myself, show how difficult it is to draw any definite line between the Upper Llandovery rock and the lowest portion of the overlying Wenlock shale. To the west of the Worcestershire Beacon, or near the north end of the chain, there occurs an impure limestone, occupying nearly the same position at the summit of the Llandovery rocks, and known as the 'Hollies Limestone' of Shropshire (pp. 90 & 91). Though this bed contains some fossils which truly belong to the lower group, such as Leptæna sericea and Orthis calligramma, yet it possesses many others which are characteristic of the Upper Silurian division.

The reader should compare my original description * of this intermediary band of limestone, as it ranges by Stumps Wood and other places west of the Malverns, with the more precise details of Professor Phillips and those by Dr. Holl.

The Upper Silurian rocks of this tract have been here partially alluded to only, p. 95, my object being to show how very different is the succession of strata beneath them to that which occurs in Shropshire and Wales, where the series is full and complete. It must however, be said that few tracts in England afford better examples for the study of the upper members of the system, as indicated in the little section, p. 95, to some features of which the attention of the reader will afterwards be called †.

The insulated district of Woolhope, within a short distance of the Malvern Hills, exhibits the smallest portion only of the Upper Llandovery rock, in the centre of that remarkable valley of elevation which, fully exhibiting the whole of the Upper Silurian series, will be treated of in the sequel. It is well, however, here to note that the major axis of that elevation is from N.W. to S.E., and consequently at right angles to the main direction of all the Silurian rocks in Wales and the bordering counties of England, and also discordant to the N. and S. line of the Malvern Hills.

Upper Llandovery or May Hill Sandstone.—At a distance of about nine miles to the south of the Malvern range, the same Upper Llandovery rocks reappear in May Hill and Huntley Hill, Gloucestershire, where also they are surmounted by Upper Silurian rocks. We have just seen that in

* See Sil. Syst. p. 415. In his luminous memoir of the Malvern and Abberley Hills, and their extension to Woolhope, May Hill, &c., Professor Phillips has skilfully and elaborately developed all the physical contortions of the strata in this district, and the mineral and palæontological characters of the rocks. By the sound philosophical reflections with which it is interspersed, he has imparted great value to a work which reflects the highest credit on the Geological Survey of Great Britain.

† As the Malvern Hills are within easy access of the Lias of the Vale of the Severn, and the Oolitic range which, extending athwart England from Whitby and Scarborough on the N.E. to Lyme Regis on the S.W., is so admirably displayed in the Cotteswold Hills and at Cheltenham, geologists have gratefully hailed the establishment of a Naturalists' Field-Club and Museum at Great Malvern (in which the late Rev. F. Dyson and the Rev. W. S. Symonds took a prominent part) for the purpose of registering all the phenomena in which this beautiful and diversified neighbourhood abounds. (See other references in Chapters VI. and VII.) I rejoice to say that, in addition to this association, six other Natural-History Clubs have been established in the Silurian Region and Border-counties, viz. the Clubs or Societies of Woolhope, Dudley, the Severn Valley, Cotteswold, Caradoc, and Oswestry.

the South Malvern section there is a great hiatus between this deposit and the fundamental stratified masses of the tract. Applying the same test to May Hill, by ascending from the lowest visible rocks, we meet there with a much greater omission.

This ascending order is best exposed on the sides of the highroad passing from Gloucester to Ross, near the village of Huntley. In approaching the higher ground, the first rock which is observed to jut out from the plain of the New Red Marls, has all the aspect of the Cambrian rocks of the Longmynd. It is a hard, siliceous, close-grained, dark-grey, schistose stone with quartz-veins, and is quarried for the use of the roads. Containing no fossils, and being much broken and contorted, this rock has no visible connexion with the overlying sandstones and shale exposed in ascending May Hill, in none of which are there any traces of either the Llandeilo or Caradoc formations, or even of the Lower Llandovery rocks.

Seeing that this boss of old slaty rock is directly upon the southern extension of the range of the rocks forming the Malvern Hills, I would adduce this fact as a support to the conclusion I have already drawn—that the crystalline and schistose nucleus of those hills is of Cambrian age.

The mass of the hilly ground, as exposed on the sides of the highroad and ranging across Huntley Hill, consists, first, of purplish and green shales and sandy beds passing into hard coarse grits, and yellowish, fine, micaceous sandstones, occasionally undulating, but on the whole dipping steadily to the W.N.W. These beds are chiefly characterized by Atrypa hemisphærica, Orthis calligramma, Rhynchonella decemplicata, with some Pentameri. They are surmounted by reddish and lightish grey sandstones and grits in which Pentameri abound, particularly P. liratus and P. lens, with Atrypa reticularis, Strophomena pecten, and S. arenacea; and these Upper Llandovery strata, occupying the dome and summit of the hill, throw off certain grey flagstones to the west. Now most of the species in these higher beds belong unquestionably to the Wenlock group: and such ought to be the case; for the upper flagstones in question pass up directly into strata constituting the true base of the Wenlock formation, as seen near Dursley Cross.

Among these fossils are Petraia bina, Palæocyclus porpita, Halysites catenularius (the Chain-coral), Cornulites, Encrinurus punctatus, Pentamerus oblongus, P. lens, Orthis calligramma and O. hybrida, Strophomena funiculata and S. pecten, Pterinea retroflexa, Mytilus mytilimeris, M. ovalis, Atrypa tumida, Rhynchonella borealis, Euomphalus funatus, Bumastus Barriensis, Phacops caudatus, and Beyrichia tuberculata or Klœdeni.

On the other hand, the following species in these same beds and those of Huntley Hill never rise into the Wenlock shale: viz. Atrypa hemisphærica, Pentameri (two species), Rhynchonella furcata, Strophomena compressa, Tentaculites anglicus, Petraia subduplicata, and Lituites cornu-arietis. The last-mentioned fossil occurs in rocks of this age at Presteign, and has, indeed, been previously described as a Caradoc or Bala form.

As above said, we see that between this Pentamerus rock and all the inferior strata there is a greater hiatus even than on the west flank of the Malverns. Infinitely less, in short, does the May Hill Sandstone exhibit any feature of that close relationship with the lower deposits which is evident in the environs of Llandovery and Llandeilo.

Tortworth, the Lickey, &c.—The same north and south anticlinal which is apparent in May Hill and Huntley Hill, is continued southwards with a bend to the east at Pyrton Passage; and, crossing the Severn, it passes into the remarkable tract of Tortworth, where the Silurian rocks, emerging from beneath the Old Red and Carboniferous formations, have been long known to geologists. There, the elevation of the axial line being less considerable than in the Malverns or at May Hill, the oldest rock visible is the Upper Llandovery sandstone with much trap-rock; and, occupying a large area, it is seen to be immediately surmounted by the Wenlock formation with two courses of limestone and feeble representatives of the Ludlow rocks*. (For details see Sil. Syst. chap. 34.)

The most eastern tracts in England where the Upper Llandovery rock has been raised to the surface are the Lower Lickey Hills in Worcestershire, and near Barr in Staffordshire, at both of which localities that rock supports the base of the Upper Silurian deposits of the adjacent tracts of Dudley and Walsall. At the Lickey, low heathy hills are chiefly composed of quartz-rocks, lithologically identical with those masses on the flanks of the Caradoc and Wrekin which have been formed by the fusion of sandstone. The Lickey quartz most probably owes its character to a similar cause, though in this case the igneous agency has not found issue at the surface in the form of trap-rock, as at Dudley further north, or in Shropshire, where such igneous rocks are rife upon a similar axial line. In other words, the Lickey quartz lies upon a line of former eruption. On its flank this rock graduates into an ordinary grit or sandstone, in which Pentamerus lens occurs, and thus all doubt of its age is removed; whilst, just as in the other tracts above mentioned, this hard, siliceous sandstone, particularly on its eastern and southern parts (Colmers and Kendal End), is conformably surmounted by a calcareous shale with a thin course of limestone, which, as at Woolhope, Corton near Presteign, and Old Radnor, contains Upper Silurian (Lower Wenlock) fossils.

Evidences have now been given to show how certain portions of the Silurian strata are omitted in variable quantities in different districts. At May Hill all the Lower Silurian rocks, including the Lingula-flags, the Llandeilo and Caradoc formations, and even the Lower Llandovery rocks, are absent, the Pentamerus (Upper Llandovery) sandstone being there seen to repose at once on hard, unfossiliferous, slaty Cambrian rock.

* Earl Ducie, who has made himself completely master of the structure and range of the rocks of this complicated district, so large a portion of which belong to him, has also added much to our acquaintance with it, by collecting several species of fossils unknown to me when I published the 'Silurian System.'

At the Malvern Hills the lowest zone, or the equivalent of the Lingula-flags, is succeeded at once by the Upper Llandovery rocks,—the true Llandeilo and the Caradoc beds being also excluded, as at May Hill. In Shropshire, or my typical tract, no such hiatus occurs; for there the original Caradoc formation exhibits a copious series of shelly sandstones (from 4000 to 5000 feet thick) rising from beneath the Upper Llandovery rock.

The reader must here, however, be reminded that in the original Silurian region there are large rocky districts of Shropshire and Radnorshire, like those of Shelve and Builth, in which the Llandeilo Flags are not followed by the Caradoc rocks. The latter formation, of such large dimensions elsewhere, has there been entirely omitted, and the older deposit of Llandeilo is at once covered by a thin band only of the Upper Llandovery sandstone, followed by the Upper Silurian shales. In those cases, it is manifest that powerful, but limited and local, oscillations of the sea-bottom have taken place, by which the black muddy sediment, with its Trilobites and Shells, was raised up to constitute the Llandeilo Flags, and was placed beyond the influence of the waters under which the true Caradoc sandstones were accumulated in many other districts. Yet the older Llandeilo rocks, so elevated, were again depressed beneath the sea, to receive on their upturned edges the accumulations of the Pentamerus band and the overlying Upper Silurian series (see sections, p. 59).

The geologist who reasoned from such phenomena only, might be led to believe that a general break had occurred in the heart of the Lower Silurian rocks, or between the Llandeilo and Caradoc formations; but in this he would greatly err, for no such hiatus exists over a large region of Wales. On the contrary, by extending our observations, we find that the absence of the great Caradoc deposit in two or three tracts is, after all, a local phenomenon, inasmuch as we recognize the spread of that formation over a wide region of the Principality, where it lies symmetrically upon the Llandeilo rocks.

When the Upper Silurian rocks shall have been described, two synoptic tables will be placed before the reader,—one showing the omissions of certain strata in some tracts and their full sequence in others, the other being a generalized table of the whole. In the meantime let us remember that, whatever may have been the amount of disturbance of the ancient sea-bottom at the conclusion of the true Caradoc deposit, there are districts both in North and South Wales where no signs of such movements can be detected, but where all the sediments, from the Llandeilo, through the Caradoc, to the Lower Llandovery rocks inclusive, seem to have succeeded each other quietly, or at all events without exhibiting any rupture in their succession. Above all, it is to be recollected that, whatever may have been the amount of physical disturbance between the lower and the upper member of the Llandovery rocks, the organic remains of that formation unquestionably connect it with the Lower as well as the Upper Silurian

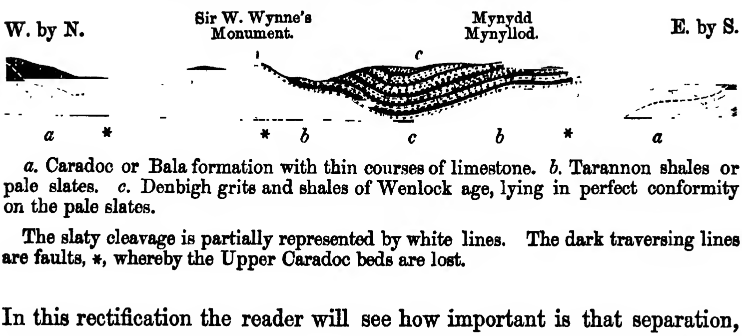
rocks, and thus display a transition from the inferior strata of which we have taken leave, into those overlying deposits whose structure and contents we are about to consider.

In illustration of the conformity to the Lower Silurian of those Upper Llandovery rocks which were formerly classed with the Caradoc Sandstone, but were subsequently determined by their organic remains to pertain to the base of the Upper Silurian, three sections are here offered.

In the first edition of this work, certain sections and their descriptions, as taken from the publications of the Geological Survey, though perfectly correct in delineating the physical data, required a different terminology.

On the revision of a large region of Wales by Mr. Aveline, under the direction of Professor Ramsay, the following points were readjusted. In the first of these diagrams, the title was changed from 'Llandeilo schists supporting Caradoc sandstone,' into "the Caradoc formation (*a*), supporting Tarannon shales (*b*) and Denbigh grits (*c*),"—the last-mentioned being known to contain Wenlock fossils, and therefore classed as Upper Silurian.

CARADOC OR BALA FORMATION SUPPORTING CONFORMABLY THE TARANNON SHALES AND DENBIGH GRITS. (Horiz. Sect. Geol. Survey, No. 35.)



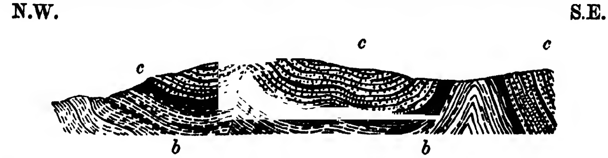
a. Caradoc or Bala formation with thin courses of limestone. *b.* Tarannon shales or pale slates. *c.* Denbigh grits and shales of Wenlock age, lying in perfect conformity on the pale slates.

The slaty cleavage is partially represented by white lines. The dark traversing lines are faults, *, whereby the Upper Caradoc beds are lost.

In this rectification the reader will see how important is that separation, of the Caradoc (Bala) from the Landeilo formation, which has been so fully explained in the preceding pages.

In the next section, the lowest beds visible are simply the Tarannon shales

BORDERS OF RADNOR AND MONTGOMERY. (Horiz. Sect. Geol. Survey, No. 27.)



b. Tarannon shales or pale slates. *c.* Denbigh grits, with grey and blue schists.

or pale slates (*b*), which in Wales occupy an intermediate space between the Llandovery rocks and the unquestionable Upper Silurian,—the overlying grits and shales, *c*, like those of the previous section, forming the base of the Upper Silurian. Again, in the third section, we have before us the

RADNORSHIRE, S. OF LLANBISTER. (Horiz. Sect. Geol. Survey, No. 27.)

N.W. S.E.

b. Tarannon shales (pale slates). *c*. Denbigh grits, &c. *d*. Wenlock shale in its ordinary characters.

true Wenlock shale, *d*, above all the masses exhibited in the previous sections.

The Tarannon shales, occasionally of hard, slaty character, and of various colours (in some places so pale a grey as to have been termed 'pale slates,' in others of purple colour), have been shown by Mr. Jukes and Mr. Aveline to form a geological band of great persistence, which, beginning, according to the last-mentioned surveyor, in small dimensions near Llandovery, expands in its course through Radnor and Montgomery, and in North Wales becomes an important subdivision. It is largely and clearly exhibited near New Bridge, and at Tarannon, between Llanbrynmaer and Llanidloes in Montgomeryshire. Fossils are rare, and those which occur do not absolutely determine whether the beds should be classed with the Upper Llandovery rocks we have been considering or with the Wenlock formation. In a physical and geological sense, Prof. Ramsay and Mr. Aveline would class them with the latter. Mr. Salter would rather connect them with the Upper Llandovery rocks. For my own part, I have only to say that they occupy the same intermediate place in the Silurian system, and connect the Lower with the Upper Silurian rocks.

However this may be, the next band, *c*, which, from its mineral character, was once termed 'Caradoc sandstone,' must clearly, through its fossils, be classed with the overlying shale, *d*, of the Wenlock formation. The sandstone, *e*, is, in short, known to be a prolongation of the 'Denbigh grits and flags,' which, from their being unconformable to the older slates and rocks, and containing Wenlock fossils, Professor Sedgwick properly considered to be the base of the Upper Silurian of North Wales*.

Among the most abundant of these fossils there is, however, one form, Rhynchonella decemplicata, which is also characteristic of the Llandovery rocks. But with it are many common Upper Silurian fossils, such as Phacops Downingiæ, P. caudatus, Spirifer trapezoidalis, Cucullella ovata,

* Quart. Journ. Geol. Soc. vol. i. pp. 19, 21.

Chonetes lata, Murchisonia Lloydii, Bellerophon trilobatus, B. carinatus, Orthoceras annulatum, &c.

In the general Table of Colours attached to the Map, these 'Denbigh grits' are therefore placed at the bottom of the Wenlock formation. But as, with the exception of parts of North Wales, where the beds are sandy, the Wenlock formation is eminently distinguished by its purely argillaceous base, these exceptional examples have been first disposed of, and we now proceed to consider the Upper Silurian rocks from their base upwards, as developed in the original Silurian Region.

CHAPTER VI.

UPPER SILURIAN ROCKS.

GENERAL CHARACTER OF THE UPPER SILURIAN ROCKS, AS DIVIDED INTO THE WENLOCK AND LUDLOW FORMATIONS.—THE WENLOCK FORMATION OF SHALE AND LIMESTONE, WITH ITS CHIEF FOSSILS, DESCRIBED IN ASCENDING ORDER, FROM THE SHALE WITH WOOLHOPE LIMESTONE TO THE WENLOCK OR DUDLEY LIMESTONE INCLUSIVE.

EXAMPLES have already been adduced to indicate the order in which the Lower Silurian rocks are overlain by the higher division of the system; and we have now, therefore, to consider the mineral characters and fossil contents of the latter as composed, in ascending order, of the Wenlock and Ludlow formations.

As the older schists and slates were assuredly at one period nothing more than marine mud, finely laminated, so is it still more apparent that such was the former state of the greater portion of the Upper Silurian; for even at the present day the latter is composed of materials for the most part similar to those of the older slates, though in a softer and less coherent state.

Whether these argillaceous masses be examined in the wilds of Radnor Forest and the eastern parts of Montgomery, in the western parts of Shropshire (Long Mountain), or in many tracts of South Wales (see Map), they present the uniform 'facies' of a thick, yet finely laminated, dark, dull-grey shale, in which hard stone of any strength or persistence is the rare exception. Their dominant character, in short, is that of 'mudstone.'

Ranging chiefly from S.W. to N.E., they rest conformably upon lower rocks, in numerous undulations *. Looking to the whole region in which these rocks are laid down upon the annexed Map (see colour No. 5), there are considerable tracts of North Wales where the lowest members of the Wenlock formation possess mineral characters which distinguish them from the types originally described in Shropshire and Herefordshire; but, as the same fossils prevail in all such cases, geological classification is unaffected by the lithological variations. The base of the deposit in Wales often consists, as previously stated, of sandstones or grits, with shales and flagstones, all more or less affected by a slaty cleavage. These have been termed 'Denbigh grits;' but as the sandy beds thicken and thin out

* The strike of the same deposits varies in different districts. Thus in North Wales the prevalent strike is nearly N.N.E. to S.S.W; in the Wenlock and Ludlow district it is nearly N.E. to S.W.; whilst in South Pembroke all the Silurian rocks range from W. by N. to E. by S., in conformity with the major axis of the great South-Welsh coal-field (see Map). The apparently conformable undulations of the Lower and Upper Silurian rocks in various parts of Wales are, indeed, represented in the diagrams already given, pp. 102, 103, as taken from the published Sections of the Government Survey.

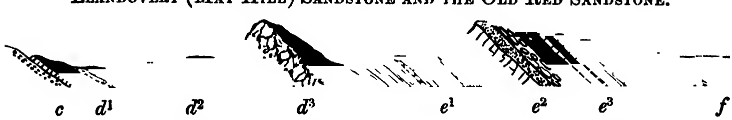
rapidly, they are simply to be viewed as local features among the great masses of shale (4^a of the Map)*. In fact, they are simply sediments which were sandy in the portion of a former sea that covered the tracts now constituting Denbighshire, and were muddy or argillaceous in more eastern areas. Passing, however, from such varied mineral conditions (for at Marloes Bay in Pembrokeshire the strata of this age are again sandy), it may be affirmed that usually the Upper Silurian rocks of Wales have been only so far affected by slaty cleavage as to leave them in that disjointed, incoherent state of mudstone (provincially 'rotch'), so useless to the mason and miner, and so cold and profitless to the agriculturist. In all such tracts, where the subdividing limestones are absent, or feebly indicated, it is only by close observation of the imbedded fossils that the formations, so clear and typical in other parts, can be recognized.

When, on the contrary, we follow the same deposits from Wales to the exemplar tracts of Shropshire and Herefordshire, where the Upper Silurian rocks were classified, and their order, character, and fossils first described, we find them diversified by interpolated courses of limestone—much calcareous matter being disseminated, both in nodules and in flagstones.

With such additions to the richness of the subsoil, so welcome to the proprietor, the geologist usually discovers a greater abundance of fossil animal remains than in the sterile siliceous or argillaceous strata, cotemporaneously formed, in the western tracts; whilst by observing the order of superposition, and by tracing the divisionary limestones, he reads off the order of the beds, and chronicles with precision the succession of their respective fossils.

In this way the Upper Silurian rocks are seen to consist, as a whole, of the two formations to which I assigned the names of 'Wenlock' and 'Ludlow,' each of these being subdivided in the manner expressed in this woodcut.

GENERAL ORDER OF THE UPPER SILURIAN ROCKS INCLUDED BETWEEN THE UPPER LLANDOVERY (MAY HILL) SANDSTONE AND THE OLD RED SANDSTONE.



c. Upper Llandovery rock, occasionally a limestone, but often a pebbly sandstone. d^1. Shale, with Lower Wenlock or Woolhope limestone. d^2. Wenlock shale. d^3. Wenlock limestone. e^1. Lower Ludlow. e^2. Middle Ludlow or Aymestry limestone. e^3. Upper Ludlow and Tilestone. *f*. Bottom of Old Red Sandstone.

The inferior member of the Wenlock formation, which rests on the Upper Llandovery rocks, *c*, as seen in Shropshire and parts of Wales, is chiefly a mass of dull, argillaceous, dark-grey shale, rarely if ever micaceous, and

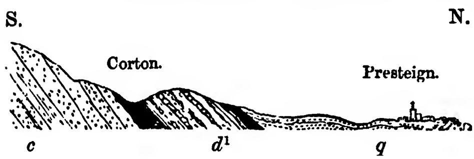
* Although the Denbigh grits are marked in the Map as 4a, to distinguish them from 4b, the Woolhope limestone, and 4c, Wenlock shale, the reader is not to infer that any difference of age is thereby implied,—the strata defined by the letters *a*, *b*, *c* being simply lithological varieties of the lower portion of the Wenlock formation usually developed as shale.

agreeing with the pale slate before alluded to. Strictly speaking, there is no continuous band of limestone subordinate to the lower shale, d^1, below the escarpment of Wenlock Edge in Shropshire, the rock to which attention is first called being there merely represented, as also in some other tracts, by a few calcareous nodules and bands of sandstone, d^2.

In following these deposits from Shropshire into Herefordshire, the great limestone, d^3, above the shale, d^2, is already found, on the banks of the Lugg, west of Aymestry, and not more than ten miles from the Wenlock Edge, to be diminished to a thin irregular stratum, chiefly concretionary. Further to the south-west, and in Radnorshire, the lime disappears entirely amid the mass of mudstones; but to the south of Presteign an inferior course of limestone is interpolated in the lowest part of the Wenlock shale. This rock, d^1 of the diagram, and which has been alluded to in the last chapter, merits special attention.

Lower Wenlock or Woolhope Limestone.—An examination of the old quarries at Corton, one mile south of Presteign, shows that this limestone is fairly subordinate to a black shale, which rests on the Llandovery grit and conglomerate before described. This superposition is delineated in the following diagram.

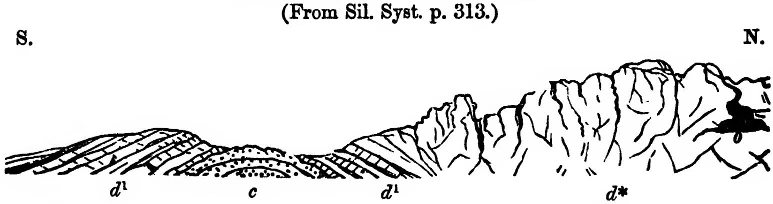
LOWER WENLOCK LIMESTONE AT CORTON, NEAR PRESTEIGN.



c. Coarse pebbly grit, known here as 'Corton grit,' with Pentamerus oblongus &c. d^1. Wenlock shale with Woolhope or Lower Wenlock limestone. q. Gravel of the Valley of Presteign.

To the south of Corton lies the large and loftier rock of Nash Scar, formed of the same limestone, which, whether thick-bedded or nodular, has been fused into one subcrystalline mass, the stratified character having been destroyed, and the shale, once associated with the limestone, obliterated, as expressed in this diagram †.

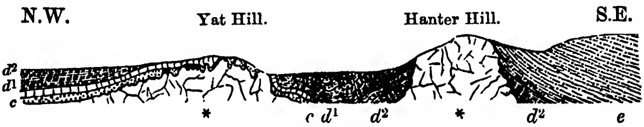
ALTERED LIMESTONE OF NASH SCAR.
(From Sil. Syst. p. 313.)



c. Arches of Woolhope limestone and shale, d^1, followed by d^*, amorphous or altered limestone. o. Caverns.

† The rocks of Nash Scar and Old Radnor are the only masses of limestone in this region; and as there are no other calcareous rocks worth burning to lime between this district and the sea-coast, they are of high value to the Welsh proprietors, the lime being transported to great distances westward (see Map).

In tracing the strata southwards along this axis, other masses of limestone, more or less amorphous, are seen near Old Radnor, which, in proportion as they approach the eruptive masses of Stanner and Hanter Rocks, and Worsel Hill, or the highly metamorphosed rock of Old Radnor and Yat Hill, are themselves subcrystalline, and unbedded, with coatings of serpentine upon the surfaces of the joints. On the contrary, in receding westwards from that line of eruption and metamorphism, into the Vale of Radnor, to the south-east of Harpton Court *, the limestone begins to resume its bedded character, resting on the Llandovery conglomerates which range by Old Radnor church and Yat Hill. Whilst the following section, taken from one of the coloured sections of the Government Survey, exhibits the syenite and greenstone of Hanter Hill throwing off the Ludlow rocks to the south-east, it is also suggestive of the belief that another body of igneous rock lies subjacent to the conglomerate and crystalline limestone of Old Radnor and Yat Hill, where the coatings of serpentine and brecciated and altered features of the stratified rocks are, in the eye of the geologist, conclusive evidences in favour of such relations.



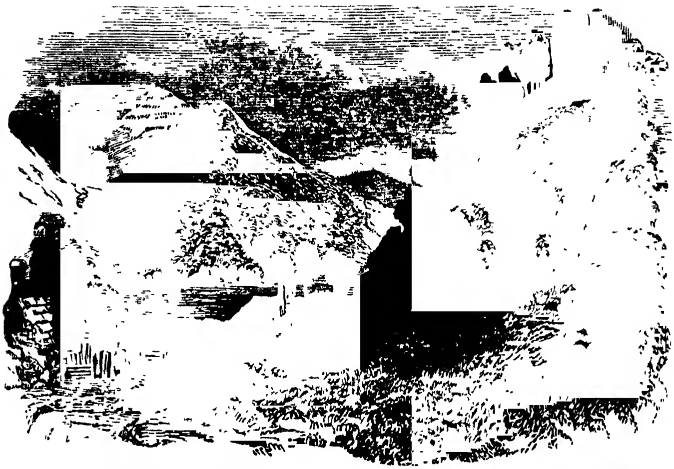
e. Ludlow rocks. d^2. Wenlock shale. d^1. Woolhope or Lower Wenlock limestone (partially altered, with serpentine faces). *c*. Upper Llandovery, in parts altered. * Eruptive rocks (syenite, greenstone, and hypersthene rock).

The eruptive rocks of this tract are highly picturesque; and as they offer, in a very small compass, phenomena which characterize large mountain-masses, a sketch of them is annexed. The spectator is placed at the south-eastern foot of Stanner Rocks, near Kington, which are charged with hypersthene: this mineral, though common in some foreign countries, and abounding at Loch Scavig, in Skye, has hitherto been found in one other British locality only.

The greater expansion of the Lower Wenlock or Woolhope limestone in Radnorshire, as compared with that of the few nodular strata of the same age in Shropshire, must doubtless have been in great measure due to the larger amount of the original calcareous deposit, the nature of which is still visible in the old quarries near Presteign. The amorphous, massive, and crystalline condition, however, of the same rock at Nash Scar and Old Radnor, was, we cannot doubt, caused by the action of heat issuing along a line of fissure, which, emitting the igneous rocks of Stanner, Worsel, and

* The seat of my esteemed friends the late Sir T. Frankland Lewis, and his eminent son, the late Sir George Cornewall Lewis: the latter first urged me to put together all my geological records of this region, and form the work called the 'Silurian System.' The many happy days I passed in their company are remembered by me with true gratification. The accomplished father passed away when somewhat ripe in years; and the fame of the illustrious statesman, who was taken from us in the summer of his days, is commemorated by a monument at New Radnor in the heart of the Silurian Region.

Hanter, fused the strata into huge amorphous masses, and left films of serpentine on the faces and joints of the altered limestone.



VIEW FROM STANNER ROCKS (WORSEL WOOD, HANTER HILL, AND HERGEST RIDGE BEING SUCCESSIVELY SEEN IN THE DISTANCE). (From Sil. Syst. p. 311.)

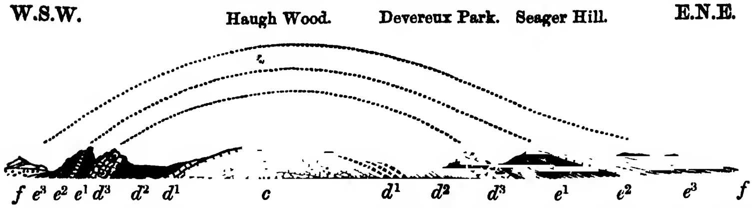
Nearly all the fossils which have been found in the limestone of this tract, whether by Mr. Edward Davis, who discovered most of them, and specially assisted me in studying them, or subsequently by the Government Geologists, are true Wenlock and Upper Silurian forms.

Some of these, such as the Trilobites Bumastus Barriensis, Phacops caudatus, and Encrinurus variolaris, with the Shells Leptæna lævigata and Acroculia prototypa, large Encrinite stems, and several Corals, are well-known published fossils of the limestones of Wenlock and Dudley *; and in addition to these, even the Pentamerus Knightii has also been found, which, as will hereafter be stated, is a marked fossil of the overlying Ludlow formation. With these, however, two fossils have been found which usually belong to a lower horizon, —the Atrypa hemisphærica and Staurocephalus Murchisoni, the former being abundant in the Llandovery rocks, whilst the latter is even a Caradoc or Bala species.

Lower Wenlock at Woolhope near Hereford, the Malvern Hills, May Hill, &c.—Let us now consider the character of the lowest calcareous member of the upper Silurian rocks exhibited in the centre of the most symmetrical valley of elevation in the British Isles, or that of Woolhope in Herefordshire. There the limestone in question, as seen in the following diagram, forms the exterior coat of a central dome, *c*, in which the summit of the Upper Llandovery (May Hill) sandstone is barely visible, and from which the Woolhope limestone, d^1, dips away on all sides, to pass

* Sil. Syst. p. 313.

SECTION ACROSS THE ELEVATED VALLEY OF WOOLHOPE. (From Sil. Syst.)



c. Upper Llandovery rock. d^1. Woolhope or Lower Wenlock limestone and shale. d^2. Wenlock shale. d^3. Wenlock limestone. e^1. Lower Ludlow. e^2. Middle Ludlow, or Aymestry limestone. e^3. Upper Ludlow. *f*. Old Red Sandstone (base of).

under the Wenlock shale, d^2, with its chief limestone, d^3; whilst these again plunge under the Ludlow rocks, *e*, and Old Red Sandstone, *f*, as displayed in this diagram. In short, the student has here before him, on either side of the central dome of Haugh Wood, a full exposition of all the Upper Silurian rocks from their base to their summit.

The phenomena of this most remarkable elliptical mass (see Map), insulated and raised up through a great area of overlapping Old Red Sandstone, were first described in the 'Silurian System,' and have since been given in still greater detail by Professor Phillips. The term 'valley of elevation' does not convey an adequate idea of this wonderful geological scene; for within the encircling ridge of Ludlow rocks, e^2, there is one parallel surrounding valley in the Ludlow shale, e^1, and another in the Wenlock shale, d^2, or between the ridge of Wenlock limestone, d^3, and the Woolhope limestone, d^1. Thus, by the elevation of the various strata around a common centre, and by the subsequent excavation of their softer members, the hill or dome of Haugh Wood has been left, by natural causes, as if it were a huge artificial intrenched camp with two encircling mounds and two circumfluent valleys.

One of the most striking features for the consideration of the geologist is, that neither the central dome nor the surrounding ridges, including the outer encircling ring of Ludlow rocks, offer a trace of drifted matter or gravel, or even any remnants of the various strata which must, in the process of elevation, have been at first bent over in the form represented by the dotted lines, and afterwards demolished. All the débris resulting from the destruction of this once great solid mass has therefore been swept out, the tract being one of clean denudation. Another striking example of a similar phenomenon, and which clearly demonstrates the intensely powerful agency of former geological causes, is seen in the heart of the Ludlow promontory (p. 124). This phenomenon will be dwelt upon in the concluding chapter*.

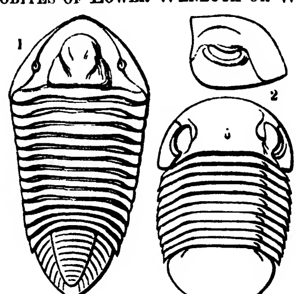
* The best mode of examining the Woolhope Valley tract is to enter it by Mordiford, through the only considerable opening by which the waters escape from the interior of the valley, and, mounting to Backbury Camp, walk along the outer ledge of Ludlow rocks, leave the magnificent Park of Stoke Edith on the left and Devereux Park, both the property of Lady Emily Foley, on the right; and passing along the crest of Seager Hill, thence cross the valley by Woolhope to Fownhope, and there rejoin the carriage-road. For details, see 'Silurian System,' with enlarged Map, &c., p. 427.

It is on the outside of the inner dome of these symmetrical elevations that the Lower Wenlock zone, as above shown, is most clearly exposed. Having been raised equably on the outward face of the dome of Haugh Wood, the nature of the calcareous deposit can be seen in detail on the sides of the roads, whilst the best limestones, which have been largely opened out since I described the tract, afford numerous fossils unknown when the 'Silurian System' was published.

In ascending order, the beds may be thus described. The top of the central dome of Woolhope, *c*, with its transition beds, is a greenish, earthy, calcareous sandstone, containing the following fossils, as described in the last chapter on the Llandovery rocks:—Pentamerus lens, Atrypa reticularis, Petraia bina. This course is followed by shale with calcareous gritty flagstones, containing the large Pentamerus liratus, Foss. 15. f. 3 (p. 90), and in the more nodular portions abundance of Leptæna transversalis and Atrypa reticularis. Layers of an impure earthy limestone succeed, containing Strophomena depressa, a species which, though occurring in the Lower Silurian rocks of North Wales, becomes much more abundant in the Wenlock formation.

In the next overlying bands of shale, we pass fairly into unequivocal Upper Silurian. In these, calcareous matter so increases as to form strong beds of dark indigo-coloured, argillaceous limestone, which is characterized by cross veins of pink and white calcareous spar. The strongest bed (about 10 feet thick) is a tough, impure, earthy limestone, largely extracted for the roads; and it is again covered by a stratum of purer limestone, followed by shale with an upper bastard limestone. Now, although the whole of the calcareous courses of this subformation have no greater maximum thickness than from 30 to 40 feet, still the rock, together with its interpolated beds of sandy shale, is seen to occupy a very great surface on the annexed Map, from its being so equably spread out at a low angle of inclination. Among the chief fossils of this limestone, which I have collected on the spot, are the two Trilobites of the following woodcut, viz. Bumastus Barriensis, Foss. 17. f. 2, and Homalonotus delphinocephalus, f. 1. There are also Phacops caudatus, Cornulites serpularius, Orthoceras annulatum, a species of Phragmoceras, Euomphalus sculptus, Spirifer elevatus, Strophomena imbrex, S. pecten, S. depressa, Leptæna transversalis, Orbiculoidea Forbesi, Atrypa reticularis, Rhynchonella Wilsoni &c., and rarely Orthis elegantula.

FOSSILS (17). TRILOBITES OF LOWER WENLOCK OR WOOLHOPE LIMESTONE.



1. Homalonotus delphinocephalus, Green.
2. Bumastus Barriensis, and profile of the head.

These figures are about one-third the natural size.

Here again, as in Radnorshire, we have a great predominance of true

Wenlock fossils, and one (the Rhynchonella Wilsoni) which, as we shall presently see, is most abundant in the highest Silurian division, or Ludlow rocks; and thus in their relative position as well as in their fossils, the Woolhope and Radnorshire limestones are identical.

The Silurian formations which range from the Malvern Hills and the Woolhope district to May and Huntley Hills in Gloucestershire exhibit the same general order of succession, accompanied, however, by modifications of the lithological and zoological distinctions of the lower member of the Wenlock formation, which it is right to notice. Instead of being the compact, hard, tough, and strong-bedded rock of Woolhope, it becomes on the western flank of May Hill a group of nodules and very irregular courses disseminated in shale, simply forming a rather more calcareous base of the Wenlock shale than what is seen under the Wenlock Edge and other places where similar nodules occur. At May Hill, as already shown, there is, indeed, an upward development from masses of Pentamerus (Upper Llandovery) sandstone beneath, into a series of interlaminated sandstones and shale, which assume, to a great extent, the fossil characters of the Lower Wenlock. In no portion of Britain, therefore, are the two formations of Upper Llandovery rocks and Wenlock shale better linked together than in the Malvern and May Hill region.

In the Malvern district the Woolhope limestone may be studied north of Storridge Farm, and north of Crumpend Hill, also at 'Ballard's quarry,' near the Wych. Dr. Holl remarks also upon an interesting fault on the road from West Malvern to Mathon Lodge, which "passes obliquely over both ends of the Woolhope limestone, so as to make it appear that there are two beds of limestone at this spot"*. It may also be seen in the picturesque valley of Netherton near Eastnor, dipping away from the Upper Llandovery beds of the Obelisk hill under the Wenlock shales and limestones.

Mr. Symonds records a great thickness of shales, which he calls 'Woolhope shales,' as intercalated, in the Malvern tunnel, between the Llandovery rocks with Pentameri and the Woolhope limestone (the position of the Tarannon shales of the Government Surveyors). They are perfectly conformable to the Llandovery beds and the overlying Woolhope limestone. Dr. Grindrod obtained from them a fine series of Trilobites and Shells, many of new species†.

This tract, so elaborately described by Professor Phillips, was also carefully studied by Sir Henry De la Beche himself, when the line of demarcation between the Lower and Upper Silurian rocks fixed upon by the Government Surveyors was made the same as that which had been originally suggested in the 'Silurian System'‡. On the west flank of the North Malverns, the sandstone with Pentamerus oblongus passes upwards into, and is interlaced with, subcalcareous bands, in which, as before said, these

* Quart. Journ. Geol. Soc. vol. xxi. p 95.
† Quart. Journ. Geol. Soc. vol. xvii. p. 158.
‡ See Sil. Syst. p. 442 *et seq.*

shells are mixed with others essentially Wenlock. After lucidly explaining how such transitions harmonize with well-understood operations in nature, and that in this locality there is no firm and hard boundary between the inferior and superior strata, Professor Phillips thus writes:—"As a general result, it is quite evident that the successive changes of organic forms, as they are exhibited to us in the successive groups of strata, are not simply dependent on the lapse of time, nor explicable as a series developed in proportion to the time, unless we survey the phenomena over very wide areas, and include in the comparative terms geological periods long enough to neutralize the influence of peculiar physical conditions. These," he truly says, "on account of their local origin, limited area of effect, and recurrence at indifferent periods, have at almost every geographical point, at some epoch or other, broken or mingled the series of organic life" *. This is and has long been my belief, as founded on extensive observation.

A limestone subordinate to shale, and bearing precisely the same relations to a subjacent sandstone as that of the localities above cited, occurs on the western and south-eastern flank of the Lower Lickey Hills in Worcestershire. There the Silurian rocks consist of Pentamerus sandstone, overlapped on its edge by shale, in which are courses of limestone (at Colmer's End), the whole having been thrust up as an irregular dome through the overlying coal-measures and red sandstone. Again, in the adjacent tract near Walsall, and between that town and the Barr Beacon, the same Lower Wenlock or Woolhope limestone, long worked at the Hay Head, dips away from a point of similar sandstone†, to pass at a gentle angle of 8° or 10° under the great body of the shale with its calcareous nodules and numerous small fossils, the whole being covered by the thick or chief limestone exhibited in the great quarries of Walsall. The rock contains nearly all the fossils found at Woolhope, and notably Bumastus Barriensis, Foss. 17, p. 111, named from the adjacent village, and called by fossil-collectors the 'Barr Trilobite,' together with many forms common to the whole formation, including Orthocerata and Corals ‡.

In this way proofs have been obtained that a limestone the real place of which was indicated in several detached districts as being inferior to the great mass of shale, is by its fossils the lowest calcareous member of the Wenlock formation.

Wenlock Shale.—The shale, which is infinitely the largest and most persistent member of the Wenlock formation, occurs both below and above the Woolhope or lower limestone,—the latter being absent in many tracts, and in others represented solely by a few small elliptical and round concretions of impure and earthy limestone. The pure shale is well exposed

* See Memoirs of the Geological Survey of Great Britain, vol. ii. p. 75. This line of thought is admirably carried out by Dr. Bigsby in his memoirs on the Silurian rocks and fossils of the State of New York, Wales, &c., Quart. Journ. Geol. Soc. Lond. vols. xiv. & xv., where he works out the statistics of genera and species as to their succession, recurrence, and extinction, and of the distribution in connexion with the mineral characters of the sediments and other conditions of the habitats of the marine animals now fossilized.

† Mr. Jukes indicated to the Geological Society the existence of this point of sandstone. See also his excellent detailed Survey of this district, Records of the School of Mines, vol. i. pt. 2. p. 240. He is now preparing a third edition of this memoir.

‡ See Sil. Syst. p. 488.

on the banks of the Severn, near Coalbrook Dale and the Iron Bridge, where it is called 'Die Earth'*, and is thence to be followed all along the escarpment of Wenlock Edge, occupying a broad valley of denudation, called Apes Dale, between that ridge and the Caradoc. In the Malvern and Woolhope districts it is also a mass of finely levigated argillaceous matter, the lower part of which is more calcareous than in Shropshire, and in parts sandy and gritty. Near Malvern, where the shale is in parts highly charged with fossils, particularly the small Brachiopoda figured in Pl. XXII., Professor Phillips estimates its thickness at about 640 feet. In some parts of Wales the Wenlock shale is as incoherent as in the adjacent English counties; but in Denbighshire, as before said, it is represented by hard slaty sandstones and schists.

The prevailing fossils of the Wenlock shale, exclusive of Trilobites and Corals, which are chiefly species unknown in the lower deposits, are Brachiopods of the genera Leptæna, Orthis, Strophomena, Atrypa, and Rhynchonella, mostly of small size. In a general way the fossils of this stratum, the chief of which are given in Plates XX. and XXII., are the same as those of the overlying limestone. Among them, however, are several common to this deposit and the Lower Silurian rocks, such as Orthis elegantula (so abundant in the slates of Snowdon), Strophomena pecten, S. depressa, Atrypa marginalis, A. reticularis, and Spirifer plicatellus. Most of these Lower Silurian forms have indeed a much greater vertical range, and pass upwards through the Wenlock high into the Ludlow formation.

Orthis biloba of Linnæus, O. hybrida, and the large, flat Orthis rustica are characteristic shells, as well as Leptæna lævigata, L. transversalis, Pentamerus linguifer, Athyris tumida, Rhynchonella rotundata, R. depressa, R. Stricklandi, R. deflexa, and R. sphærica, and, in more western tracts, R. navicula.

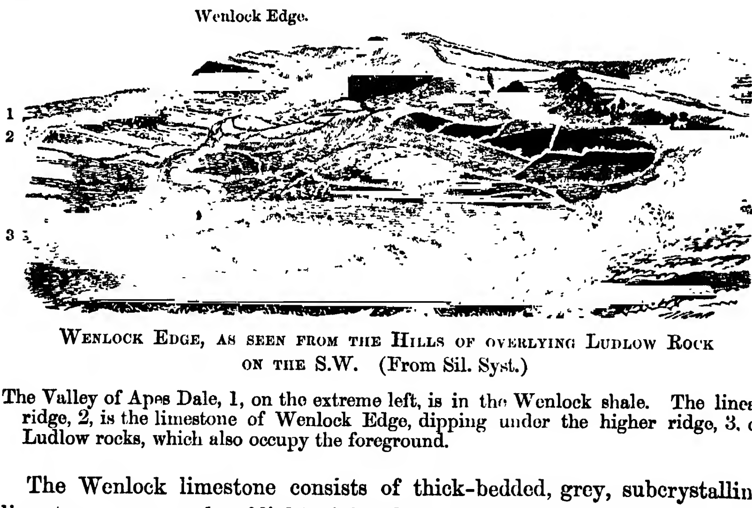
Aviculæ, Ctenodontæ, and some other bivalve Shells occur frequently; but few of them are characteristic except the Cardiola interrupta. Of spiral Shells, Euomphalus funatus and E. alatus, Pileopsis haliotis, Turbo (?) cirrhosus, Bellerophon Wenlockensis, with B. dilatatus, are the most common. The Pteropod Mollusks Theca Forbesi and T. anceps are not scarce. Certain Orthocerata, such as Orthoceras annulatum, O. filosum, and O. angulatum, are rare; but many of the thin-shelled species, O. subundulatum, O. primævum, and others abound in these muddy sediments. They are almost the only shells in this formation as it is exhibited in Denbighshire and other parts of North Wales, and occur there in the greatest abundance. Phragmoceras of one or two species, and certain Lituites, *e.g.* L. articulatus, L. Biddulphi, and occasionally L. giganteus, are conspicuous forms; but the two last-mentioned genera are not commonly met with.

Of Trilobites, Encrinurus punctatus and E. variolaris, Calymene Blumenbachii and C. tuberculosa, Phacops caudatus and its variety P. longicaudatus, are characteristic; but one of these, the Calymene Blumenbachii, is known in the rocks of Snowdon. The genera Trinucleus, Asaphus, and Ogygia are never detected even

* So called because this stratum lies beneath all the mining-ground.

in the lowest part of the Wenlock group, these forms being essentially characteristic of the Lower Silurian rocks. Cornulites serpularius, Pl. XVI. f. 6, and other Annelides are sometimes found, as well as stems and portions of Encrinites, though the perfect fossils are very rare in the typical region. With respect to Corals, it may be stated generally that they are the same as those of the Wenlock limestone, but fewer in number,—the Cup-corals Cyathophyllum, Omphyma, &c., with Favosites alveolaris, and Stenopora fibrosa, being the most conspicuous. Graptolithus priodon, which is a most abundant and characteristic fossil of the Wenlock shale, has been already figured as occurring in the Lower Silurian rocks, Foss. 12. f. 3, and Pl. XII. f. 1, 2.

Wenlock Limestone.—The upper member of the formation is a limestone, usually of lighter grey colours than the lower calcareous band already described under the name of Woolhope or Lower Wenlock. Although it is in every respect identical with the well-known limestone of Dudley, I named the rock after the sharp rectilinear ridge of Wenlock (see Map), because its relations to inferior and superior deposits are there better seen than in any other part of the British Isles, as exhibited in this sketch.



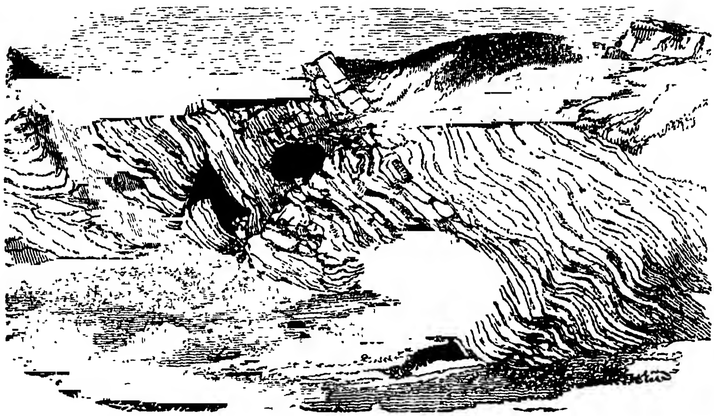
WENLOCK EDGE, AS SEEN FROM THE HILLS OF OVERLYING LUDLOW ROCK ON THE S.W. (From Sil. Syst.)

The Valley of Apes Dale, 1, on the extreme left, is in the Wenlock shale. The linear ridge, 2, is the limestone of Wenlock Edge, dipping under the higher ridge, 3, of Ludlow rocks, which also occupy the foreground.

The Wenlock limestone consists of thick-bedded, grey, subcrystalline limestone, very rarely of light-pink colour, and in parts argillaceous. In other parts of the Wenlock Edge, the rock is more crystalline; and where varied colours prevail, the matrix being charged with Encrinites and Corals, it forms a pretty marble, though the slabs are of no great dimensions. The mass is essentially of a concretionary nature, and thus differs much from the flat-bedded Lower Wenlock or Woolhope limestone, being for the most part marked by nodules of small size. Occasionally, however, the concretions are large, and are then locally termed 'ballstones.'

This limestone is underlain and overlain by shale of pale-grey and greenish tints, copiously charged with small nodules of argillaceous lime-

stone, of very irregular persistence. The 'ballstones' (some of which near Wenlock have a diameter of 80 feet), being more crystalline than the nodules or 'bumbles,' have been quarried out as the best flux for the smelting of iron; and their extraction has left caverns in the quarries, as shown in this woodcut.



OLD QUARRIES IN THE WENLOCK LIMESTONE.

The dark cavities indicate the places from which the 'ballstones,' or best crystalline limestone, have been extracted. The fossils chiefly occur in the surrounding layers of impure earthy limestone and shale.

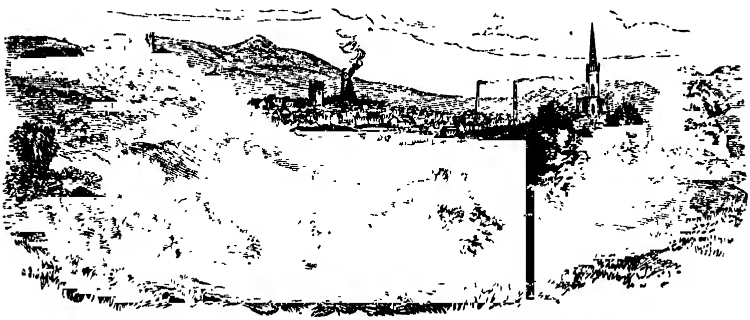
But though very thick near Wenlock, this limestone thins out so rapidly in its range to the south-west, that even in the interior of the Ludlow promontory, as displayed in a diagram to be afterwards given, it is represented by thin courses made up of small concretions only; and on the banks of the River Lugg, west of Aymestry*, it is merely represented by a few concretions, varying in size from 2 inches to 2 feet, but still full of beautiful and characteristic Corals. Thinning out entirely in Radnorshire, it is scarcely to be recognized throughout the counties of Brecon, Carmarthen, and Pembroke, its place being only marked in the cliffs of Marloes Bay, west of Milford Haven, by some fossils and a small quantity of impure limestone immersed in grey and sandy shale.

In the districts of Malvern, Woolhope, May Hill, and Usk, however, the Wenlock limestone is copiously and instructively developed; and in numberless natural sections and quarries exhibits characters similar to those which it possesses in Shropshire. On the west flank of the Malverns, where in the Ridgeway of Eastnor Park it assumes the same linear outline as at the Wenlock Edge, the limestone is estimated by Professor

* In both of these localities the Wenlock limestone was first traced by my friend the Rev. T. T. Lewis, who liberally gave to me many of the characteristic corals and other fossils figured in the 'Silurian System.'

Phillips to be 280 feet thick. There, in the flexures extending to Ledbury, it is admirably exposed, in connexion with the overlying Ludlow formation (see section, p. 95). At Woolhope it forms the encircling ridge between two parallel valleys, the one in the Wenlock shale, and the other in the Ludlow shale (see section, p. 110). In fact its ridge-like character is a necessary consequence of the superior hardness of the rock, in relation to the adjacent soft, argillaceous masses.

To the north of the town of Dudley, this limestone rises up into domes called the Castle Hill and Wren's Nest, which, with other, smaller elevations, have been protruded from beneath the surrounding coal-strata. The Castle Hill is in the accompanying woodcut represented to the left hand of the spectator, who is standing on the slopes of the Wren's Nest, and looking southwards over the town of Dudley to the hills of basalt near Rowley.



Castle Hill. Rowley Hills. Hagley Hills.

DUDLEY, FROM THE WREN'S NEST.

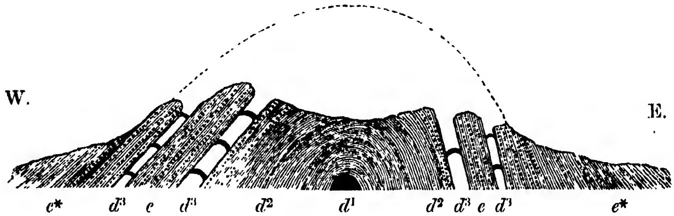
(From a Drawing by Lady Murchison: Sil. Syst. p. 480.)

As the signs of violent igneous action and dislocations of the strata are apparent, both in the subterranean works of this rich mining tract, and near the various outbursts of basaltic and trappean rocks which have been extruded to the surface (Rowley and Pouk Hills, &c.), it is fair to infer that these domes were thrown into their inflated and arched form by subterranean forces of expansion *. The Wren's Nest and Castle Hill thus exhibit on each of their opposite sides two courses of a limestone which, from its superior quality, has been worked out, first in open quarries and afterwards by deep galleries. The annexed diagram, exhibiting a section through the Wren's Nest, shows how the two bands of the best limestone,

* See the account of the igneous rocks of this district, Sil. Syst. p. 496. First described by Mr. Keir and others, and subjected to experiments by Mr. Gregory Watt, their subterranean relations to the strata have since been ably explained by Mr. Blackwell of Dudley. See also Mr. D. Forbes's account of these trap-rocks in the Geol. Mag. No. xix. p. 23; and Report Brit. Assoc. 1865, Trans. Sect. p. 53. The descriptions of these and other phenomena connected with the region around Dudley are given in detail by Mr. J. Beete Jukes, Records of the School of Mines, vol. i. pt. 2. p. 237.

d^3, have been extracted, leaving only a few arches for support; whilst the other beds, consisting of impure and nodular earthy limestone with much

SECTION ACROSS THE WREN'S NEST.
(From Sil. Syst. p. 484.)

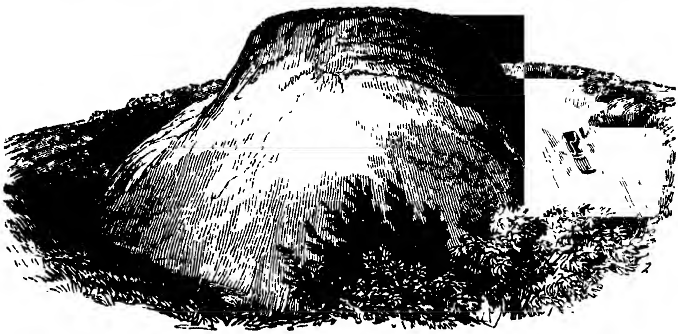


d^1. Lowest Wenlock shale (place of Woolhope limestone ?). d^2. Wenlock shale. d^3. Two bands of limestone separated from each other by 'bavin,' *e*. They are represented by the white spaces, from which the best limestone has been quarried, leaving only arches of support. *e**. Overlying 'bavin' or shale, passing up into Ludlow rocks.

shale, locally called 'bavin,' thus form the framework of the hill. The dotted arch indicates what the dome might have been, probably never entire, whilst the tinted portion of the drawing represents the body of the hill, the upper surface of which, having been hollowed out towards the centre, has obtained for it the name of Wren's Nest. It is therefore an elevated dome, which may have been produced by lateral pressure, and was probably truncated at its summit during the same period of disturbance and denudation which gave to the mass its peculiar form.

When viewed from below on its southern face, and where necessarily the excavated depression on the summit cannot be seen, the flank of the dome of shale or 'bavin,' whence the limestone has been entirely removed, presents the appearance shown in this sketch.

THE SOUTH END OF THE WREN'S NEST.
(From a Sketch by the late Rev. W. Whewell, D.D. Sil. Syst. p. 485.)



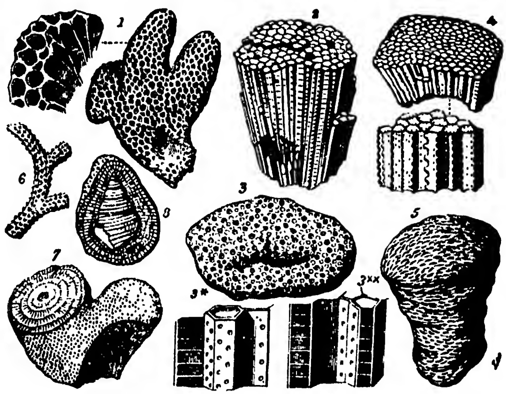
The spectator, looking to the north, sees how the limestone strata fold over a central dome of shale.

In the exterior of the nucleus, which also consists of shale, the calcareous matter disappears; but the limestone itself is quite similar, in composition and colour and in its large ballstones as well as small concretions, to the rock at Wenlock.

At Woolhope in Herefordshire (see p. 110, and woodcut) a similar uprise from the centre has produced, as we have seen, a much grander phenomenon. In the Silurian region the Wenlock formation has seldom a greater thickness than 1000 feet; but in Wales, though void of limestone, it occasionally assumes more than double those dimensions.

The most prominent fossils of the limestone, among which Corals abound, have long been known to collectors, who have derived their chief supplies from Dudley and its environs. Those persons who are searching for Wenlock fossils may, however, be told that their labour will probably be better rewarded by a visit to the northern end of the Wenlock Edge, near Coalbrook Dale, than to Dudley; for the Corals, Encrinites, and Shells along this rich escarpment are easily detached from the matrix, and the quarries

FOSSILS (18). CORALS &c. OF THE WENLOCK LIMESTONE.



1. Favosites cristatus, Blum. 2. F. Gotlandicus, Linn. 3. A variety of this Coral; and 3*, 3**, magnified portions of two varieties. 4. Favosites asper, d'Orb. 5. Alveolites Labechii, Milne-Edw. 6. Ceriopora oculata, Goldf.? 7. Favosites fibrosus, Goldf. 8. A variety incrusting Shells.

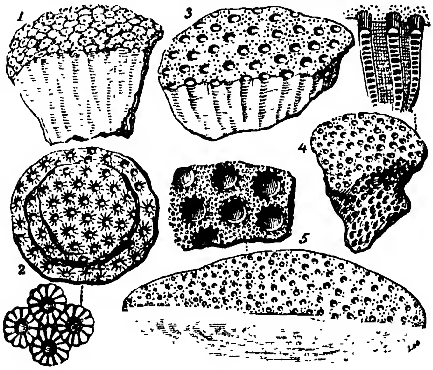
have not yet been exhausted. Benthall Edge, for example, which overhangs the Severn in so picturesque a form, and Gliddon Hill are excellent localities †. This rock is indeed distinguishable from all the inferior strata by the very great abundance of its Corals, the profusion of which makes it resemble in many places a coral-reef. These Corals were admirably described for me in the original 'Silurian System' by my valued friend Mr. Lonsdale, who made the first effort to classify them and to compare them with the determinations of continental naturalists.

† Some of the finest Corals originally published in the 'Silurian System' were collected by the Rev. T. T. Lewis, in the gorge of the River Lugg, above Aymestry.

In addition to the universal Chain-coral (Halysites catenularius, Foss. 20. f. 6) and the Favosites fibrosus (Foss. 18, f. 7), which are often met

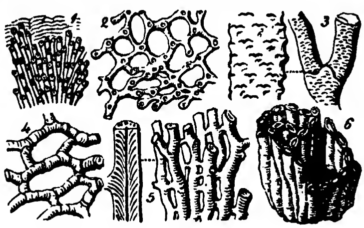
FOSSILS (19). CORALS OF THE WENLOCK LIMESTONE.

Millepore Corals of the genus Heliolites, most nearly related to the 'Blue Coral' Heliopora cærulea, Blainv.) of the Australian coral-reefs.



1. Heliolites tubulatus, Lonsd. 2. H. petaliformis, Lonsd. 3. H. interstinctus, Wahl.; a variety with large tubes. 4, 5. H. interstinctus, Wahl.; ordinary variety.

FOSSILS (20). CORALS &C. OF THE WENLOCK LIMESTONE.



1. Diastopora? consimilis, Lonsd. 2. Young of Syringopora bifurcata, Lonsd. 3. Cœnites juniperinus, Eichw. 4, 5. Syringopora bifurcata, Lonsd. 6. Halysites catenularius, Linn.

with in the Lower Silurian rocks (see Chap. IX.), the following species of Corals are everywhere typical of the Wenlock Limestone:—

Heliolites interstinctus, Foss. 19. f. 3, 4, 5, both the large- and small-celled varieties; H. tubulatus, f. 1; H. petaliformis, f. 2; Favosites asper, Foss. 18. f. 4; F. cristatus, f. 1; Cœnites juniperinus, Foss. 20. f. 3; Syringopora bifurcata, f. 4, 5, and its young or creeping form (Aulopora serpens, Sil. Syst.), f. 2; Omphyma turbinata and O. subturbinata (see Chap. X.); Alveolites Labechii, Edw.; Cyathophyllum truncatum, Linn., and C. articulatum, Wahl.; Acervularia luxurians, Eichw., with many others*.

Of the Crinoids, the more perfect only of the forms published in my old work are reproduced in the plates of this volume. Perhaps the large

* In the above three woodcuts some of the most frequent Corals of the limestone are figured. Here, as in the subsequent chapters on organic remains, the nomenclature differs in a rare instance only from that of Milne-Edwards and Haime ('Polypiers Fossiles'). Thus the genus Heliolites is not divided into three genera; whilst a few of the species are still regarded as being identical with Devonian forms. See M'Coy's Description of the British Palæozoic Fossils in the Geological (Woodwardian) Museum of the University of Cambridge.

species Periechocrinus moniliformis, Pl. XIII. f. 1, 2, is the most characteristic; it covers large surfaces of the limestone at Dudley, and is found in disjointed fragments in many other localities.

Among the Mollusks of this formation, which are figured in Plates XX. to XXXIII., Orthoceratites are very abundant, Orthoceras annulatum and O. Brightii being frequent species. Bellerophon dilatatus, B. Wenlockensis, and the singularly beautiful Conularia Sowerbyi, Pl. XXV., are characteristic. Among the most frequent spiral shells are five species of Euomphalus, viz. E. carinatus, E. sculptus, E. discors, E. funatus, and E. rugosus (Plates XXIV., XXV.).

Ordinary Bivalve Shells are less common; but Orthonota cingulata, Avicula reticulata, Pterinea retroflexa and Pt. planulata, the last figured in Chap. X., are abundant species. Of Brachiopods, Strophomena euglypha, S. filosa, and especially S. depressa, Pentamerus galeatus, Spirifer plicatellus (S. radiatus and S. interlineatus, Sil. Syst.), S. trapezoidalis, S. crispus, and S. elevatus, Orthis rustica, O. elegantula, and O. hybrida, Leptæna transversalis and L. lævigata *, are all described in the 'Silurian System.' With them are Atrypa reticularis and A. marginalis, besides several plaited Terebratulidæ, of which Retzia cuneata, Pl. XXII., and R. Salteri, Davidson, are often plentiful; but the Rhynchonella borealis (Terebratula lacunosa of my old work) is by far the most common species. Rhynchonella Wilsoni and a small variety of R. nucula are also sometimes abundant (see Pl. XXII. and woodcuts in Chap. X.).

Trilobites are very common; the most frequent of them is the Calymene Blumenbachii, formerly called the 'Dudley Locust' (Pl. XVIII.), a species which, as we have seen, also occurs deep in the Lower Silurian rocks, and, as we shall presently find, ascends also into the Upper Ludlow.

Other forms of these creatures are also prevalent; a few may be noticed. Encrinurus punctatus and E. variolaris, figured in Chap. X., are very common in both the limestone and the shale. Phacops Downingiæ is one of the most characteristic Trilobites, particularly in the environs of Dudley. Phacops Stokesii (Calymene macrophthalma of my former work), Ph. caudatus, Acidaspis Brightii, and Cheirurus bimucronatus (see Pls. XVIII. & XIX.), are frequent fossils, and, as before stated, belong also to inferior formations. Phacops caudatus is especially abundant in the Malvern Hills; whilst Calymene Blumenbachii is the reigning fossil at Dudley. Bumastus Barriensis and Homalonotus delphinocephalus, which have been cited from the Lower Wenlock or Woolhope limestone, are also found in this rock, the former very frequently. The Annelides Cornulites serpularius and Tentaculites ornatus occur on almost every specimen of the limestone at Dudley.

In the above mentioned districts, the Wenlock limestone passes upwards gradually into a thick mass of pale-coloured shale, undistinguishable from that beneath the solid rock. From the physical relations of this shale, and from its forming usually a part of the same hills as the mass of the Ludlow rock, it is classed with that formation, though the reader must understand that in reality it is only an intermediate band intimately

* See Plates XX. to XXII.

uniting the Wenlock and Ludlow in the Upper Silurian group, and is almost equally connected with both by structure and fossil contents.

Since the preceding paragraph was published in the last edition of 'Siluria,' Mr. C. Ketley has shown, in a paper read before the British Association in 1865, that so many fossils which characterize the Wenlock limestone occur in this superjacent shale, that it ought to be classed with the Wenlock formation and not termed Lower Ludlow rock. This arrangement would agree with my own view, so far as regards the tract of Dudley, or wherever the cover of shale upon the limestone has no great thickness; but it would be quite inapplicable to many parts of the Silurian region, where the vast thickness of shale which supports the Ludlow or Aymestry limestone must continue to be classed, for reasons to be assigned, with the superior formation as Lower Ludlow rock.

A further acquaintance with the fossils of the Wenlock formation must be obtained by consulting the 10th Chapter, as also the descriptive monographs mentioned in the Preface. The main object of the present work is not to direct attention to rare forms, but chiefly to those which are characteristic of the rocks.

CHAPTER VII.

UPPER SILURIAN ROCKS (*continued*).

THE LUDLOW FORMATION, GENERAL CHARACTER OF.—ITS SUBDIVISION IN THE TYPICAL DISTRICTS, INTO LOWER LUDLOW ROCKS, AYMESTRY LIMESTONE, AND UPPER LUDLOW ROCKS.

IN a general sense, the Ludlow rocks of the Silurian region of England and Wales must be simply viewed as a continuation of the argillaceous masses which prevail in the underlying Wenlock formation. Such is more particularly the case in the lower beds of this deposit. The central portion, however, in several tracts, particularly at Aymestry, consists of an argillaceous dark-grey limestone. The upper member being more sandy and somewhat calcareous, yet retaining in parts much of the 'mudstone' matrix, is in great measure an imperfect, thin-bedded, grey-coloured,

LUDLOW CASTLE.

(From a Sketch by Lady Harriet Clive, now Baroness Windsor. Sil. Syst. p. 195.)

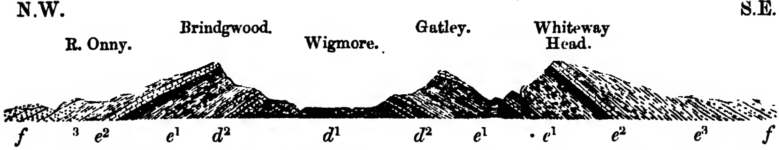
In this sketch the River Teme is seen to flow in a chasm of the Upper Ludlow Rocks, the strata on which the spectator is supposed to be standing being the same as those on which the Castle is built. The basalt of the Titterstone Clee Hill is in the distance, surrounded by Old Red Sandstone, and covered by Carboniferous deposits.

earthy building-stone. Occasionally the highest stratum is composed of light-coloured sandy freestones and tilestones, through which the formation graduates lithologically and conformably into the lowest beds of the Old Red or Devonian rocks.

Such is the general order near the town of Ludlow, which stands upon the higher strata of the formation, as shown in this woodcut. Its central and inferior masses are best seen either in the escarpments of the adjacent hills on the S.W., or in that ridge which for a distance of twenty miles on the N.E. is interposed between the Wenlock Edge and the Old Red Sandstone of Corve Dale and the Clee Hills. The section here given will

convey an adequate idea of the succession. (See also Map, and Section beneath it.)

SECTION ACROSS THE LUDLOW PROMONTORY *.
(From Sil. Syst. pl. 31. f. 5.)



d^1. Wenlock shale. d^2. Wenlock limestone. e^1. Lower Ludlow beds. e^2. Aymestry or Ludlow limestone. e^3. Upper Ludlow beds. *f*. Old Red Sandstone (bottom beds of).

In following the formation from the Ludlow tract on its strike or direction to the S.W., its included limestone, like that of the subjacent deposit, is also soon seen to thin out and disappear. Scarcely has the geologist quitted the north-western corner of Herefordshire, than he finds the central band attenuated to a mere course of calcareous grit, which is entirely lost in Radnorshire. There the Upper Silurian rocks of the mountain of Radnor Forest, which are laid open in the ravine of 'Water-break-its-Neck' and other gullies, expose a gradual succession from the Wenlock through the whole of the Ludlow formation up to the junction-beds of the Old Red Sandstone, and with scarcely a trace of limestone. As such also the formation ranges for the most part through Brecon and Carmarthen, the central part being nowhere a workable limestone, and only here and there calcareous, except through the occasional presence of a few testaceous remains. In Marloes Bay, Pembrokeshire, where the Silurian rocks are exposed in the sea-cliffs (see the view at the end of this chapter), it is difficult to say more than that sandy calcareous shale and very impure limestone containing Wenlock fossils are surmounted by ferruginous and hard sandstone, rarely calcareous, and in parts a conglomerate.

In the Clyro and Begwm Hills, however, or along the eastern frontier of the Silurian rocks, extending from Kington towards the south-west, the Ludlow rocks retain much of their typical characters, and particularly on the banks of the Wye, between Builth and Hay, where I first observed their relation to the Old Red Sandstone. (See Map and Sil. Syst. p. 312.)

Let us now consider the nature of the different members of the Ludlow formation, where they are most conspicuously characterized by the greatest quantity of fossil remains.

Lower Ludlow Rocks.—These strata, which are, I repeat, simply an upward prolongation of the Wenlock formation, are composed of dark-grey shale, rarely micaceous, with small concretions of impure limestone. My

* Like the Woolhope Valley and all of the so-called Valleys of Elevation, including the grand tract of the Wealds of Sussex, Surrey, and Kent, this Valley of Wigmore, and the lateral valley between Gatley and Whiteway Head, are entirely denuded and swept clear of all débris, foreign or local.

chief reason for grouping them with the Ludlow rather than with the Wenlock deposit was, that throughout the typical districts of Shropshire and Herefordshire these shales occupy the base of the ridges, the harder summits and outward slopes of which are composed of Aymestry limestone and Upper Ludlow rocks.

The clearest and finest examples of such physical features are seen in ascending from the denuded valley of Wigmore, in which the Wenlock shale, d^1, and limestone, d^2, are exposed as in the opposite woodcut, and thence by a depression in the Lower Ludlow, e^1, which ranges into the Mary Knoll Dingle and Comus Wood *, until you reach the stronger stony masses of the Aymestry limestone, e^2, and Upper Ludlow rock, e^3.

The inferior strata, e^1, for the most part argillaceous, are often arranged in large spheroidal masses, showing a tendency to concretionary structure, which rapidly exfoliate under the atmosphere and break into shivery fragments. Calcareous nodules, differing only from those of the Wenlock deposit in being usually of a blacker colour, have often been formed round an Orthoceras, a Trilobite, or other fossil as a nucleus.

One of the most prevalent of these organic bodies is our old friend Calymene Blumenbachii, whose acquaintance the collector may have first made in the much lower rocks of Caer Caradoc and Snowdon. (See also Chap. IX.) It is accompanied very frequently by the long-tailed Trilobite now called Phacops longicaudatus. These two may be considered to be the characteristic Trilobites of the formation, though there are several other species; and with them, the Graptolithus priodon (or Ludensis †), also a Lower Silurian fossil, occurs abundantly. The persistence of these typical species clearly proves the indivisibility of the Silurian system of life. Nor are Cardiola interrupta, Pl. XXIII. f. 12, and Murchisonia Lloydii, Pl. XXIV. f. 5, less characteristic.

In ascending, the strata become somewhat more sandy, constituting thick, earthy, and very slightly calcareous flagstones, the flaglike separation being due to laminæ of sand. These beds, the 'pendle' of the workmen, were formerly pointed out as being distinguished by containing large Orthoceratites. Recently they have attracted much attention at a spot near Leintwardine, and have yielded, to the persevering search of the geologists of Ludlow and its environs, remains of many Crustacea and abundance of peculiar Starfishes ‡. Figures of some of the latter are given at p. 127.

These flaglike strata form the support of the Aymestry or Ludlow limestone, from which they are usually separated by soft soapy beds, in parts an imperfect fuller's earth. It is the decomposition of this unctuous

* Milton passed some time in Ludlow Castle, then a border Welsh fortress, and his 'Mask of Comus' was performed in it. Comus Wood is in one of the deep depressions which vary the surface of the Ludlow promontory.

† Ludensis is the Latin word signifying 'of Ludlow.'

‡ Colonel Colvin of Leintwardine, and Messrs. Lightbody, Cocking, and Marston of Ludlow, have the merit of these last discoveries. Formerly Mr. Proctor contributed much from the neighbourhood of Leintwardine.

fuller's earth (provincially 'Walker's earth') beneath heavy masses of the limestone, which rest upon it, which has occasioned numerous landslips both near Ludlow and in other parts of Herefordshire, one of the most striking of which will presently be mentioned.

The lower shale occupies the escarpments and contiguous valleys of the Ludlow rocks which range from Shropshire by Presteign to Radnor Forest, and also large undulating tracts of the western parts of Shropshire or contiguous parts of Montgomeryshire, such as the Long Mountain and other tracts around Welshpool and Montgomery (see Map). From the steeps and valleys west of Kington, it extends, together with the upper members of the Ludlow rocks, to the banks of the Wye, and is finely exposed in the noble escarpment at the western end of the Forest of Mynydd Epynt in Brecknockshire. A good idea of the features of that tract is conveyed by a sketch already given, p. 58, where the rounded outline of the hills in the middle ground, as seen from the slaty hills on the west, is due to the soft nature of this deposit. The same rock is also well developed in the Malvern tract, where Professor Phillips assigns to it a thickness of about 750 feet. (See also section, p. 95.)

In the Woolhope elevation and the group of Usk, or as lying between the Dudley and Sedgeley (Wenlock and Aymestry) limestones in Staffordshire, it is everywhere the same dull, non-micaceous shale, which, from its incoherence, has been denuded for the most part, thus giving rise to a deep valley which separates the harder parts of the Wenlock and Ludlow rocks from each other.

In the environs of Ludlow, and in many parts of the Silurian region, this inferior member of the Ludlow rocks, whilst containing several forms of Trilobites found also in the strata above and below it, is specially characterized by a profusion of straight or curved Chambered Shells. Such are the Orthoceras, Lituites, and Phragmoceras, a genus named by my old friend the late W. Broderip, the eminent naturalist, and which was unknown before the publication of the 'Silurian System.' Orthocerata abound, not less than eleven species having been figured as characteristic of this rock. But extended researches have shown that, in this case as in many instances of other fossils alluded to, several of these Chambered Shells occur in much older as well as younger members of the system.

In the rich locality already spoken of, viz. Church Hill, Leintwardine, the usual fossils of this rock have been found associated with Starfishes and that singular Crustacean the Pterygotus, together with some other forms, and among them a fragment of the Fish Pteraspis. This last discovery has of course modified my former belief, that the fishes in the upper part of the Ludlow formation were the oldest known ichthyolites. But, after all, the modification is slight; for still the position of this Pteraspis is scarcely beneath the real centre of the Ludlow formation as a whole.

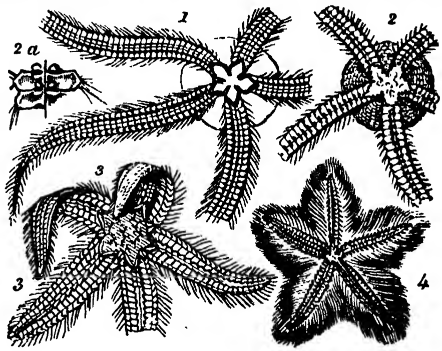
The Pterygotus belongs to a distinct species from that found in other localities, and has been described by Mr. Salter under the name of P. punctatus. It was apparently of great size, perhaps seven or eight feet in length; but its fragments

need not be figured here. Some remarks on the principal species will be given at the end of this Chapter.

The Starfishes, some of which are here delineated (Foss. 21), are considered to belong to genera, perhaps to families, distinct from any living forms. One of them, Palæocoma (figs. 3, 4), resembles, indeed, certain living rare forms of Starfish (Pteraster) in the great length of the spines, which, however, are longer in the fossil than in the living genus. Palasterina, M'Coy, is more like the Palmipes roseus. Others (Protaster, figs. 1, 2) have the general form of the Ophiuræ or Brittle-stars, to which they are allied, but differ in the number and arrangement of the component plates of the skeleton. No less than ten species of Starfishes have already been found here; and new forms of great beauty are occasionally discovered.

FOSSILS (21). STARFISHES OF THE LOWER LUDLOW ROCK.
(See also Foss. 57, for other Upper-Silurian Starfishes.)

1, 2. Protaster uridæ with numerous plates.
2 *a*. Small portion of a Protaster, magnified.



3. Palæocoma Marstoni, Salter.
4. P. Colvini, id.
These are Starfishes allied to Palmipes and Pteraster.

Among the Orthocerata, the largest, and perhaps the most common, are Orthoceras Ludense, Pl. XXVIII. f. 1, and O. filosum, Pl. XXVII. f. 1; these are generally accompanied by a smaller, thin-shelled species, which appears to be the O. subundulatum of Portlock. The others, though often found, are by no means so abundant or characteristic. Of Lituites, the only common species is a very large one, eight or ten inches in diameter—the L. giganteus of Pl. XXXIII. f. 1, 2, 3. The Phragmoceras, above noticed, is a remarkable shell, with the mouth or opening contracted into the shape of a key-hole. Some of its forms are flattish, broad, and shaped like a hatchet-head (Pl. XXXII.); whilst others, known as the pear Orthoceratites (Pl. XXX.), are suddenly swollen into a balloon-like shape above, and end in a tapering point below.

Of Lamellibranchiate Shells, Cardiola interrupta, Broderip, is the most common (Pl. XXIII. f. 12); yet the same species, formerly believed to be peculiar to this zone, has also been found in the Caradoc formation! Another Bivalve equally characteristic, and as yet known only in Upper Silurian rocks, is the Cardiola striata (Pl. XXIII. f. 13); and, in company with the chambered shells above noticed, it is to be found in all the fossil-bearing localities of Shropshire and the neighbouring regions. Orthonota rigida, Pl. XXIII. f. 8, and Pterinea retroflexa, f. 17, are not so common; and the latter is far more frequent in the Upper Ludlow rock.

Indeed many species of fossils have been obtained both in this stratum and the Wenlock formation, especially Brachiopodous Shells. Among these may be

cited Pentamerus galeatus, Strophomena depressa and S. euglypha, Leptæna lævigata, Atrypa reticularis, and Rhynchonella Wilsoni. Scarcely any Brachiopod is strictly peculiar to it, unless it be the small but characteristic Lingula lata, Pl. XX. f. 6. In this view, the Lower Ludlow shale might be classed with the Wenlock formation; but the other forms of Mollusks, above noticed, give to it a distinct character, and entitle it to rank locally as a separate subformation.

*Aymestry or Ludlow Limestone**.—The want of persistence over wide areas of any mass of solid limestone in the centre of the Ludlow formation has been adverted to. In some parts of South Wales, where the calcareous matter is absent, it is difficult to trace even the place of this band in the Ludlow rocks; but in Herefordshire and Shropshire, and again at Sedgeley in Staffordshire (near Dudley), it is a dark-grey limestone, worked rather extensively for use. Even where the lime is sparingly distributed, the rock is a highly calcareous flagstone, and may generally be recognized by its well-defined joints and predominant fossils.

This central member of the Ludlow formation was named by me after the beautiful village of Aymestry, where the rock is well laid open, and its relative position as well as fossil contents were elaborately worked out by my friend the late Rev. T. T. Lewis†. The clear distinction of this rock from the Wenlock Limestone was, indeed, first made by him; so that,

WHITEWAY HEAD. An escarpment of Aymestry Limestone. Strata dipping to the S.E. (From Sil. Syst. p. 243. Sketched by the late Rev. W. R. Evans.)

* In a communication to the Geological Society in 1863, Mr. Lightbody stated, after observations by himself and Mr. Marston, that, in portions of the Ludlow promontory which are much dislocated (Mocktree Forest), certain beds hitherto included in the Upper Ludlow rocks ought to be, from their fossils, classed rather with the Aymestry Limestone. Again, indicating that this limestone is more naturally connected with the lower rock, he asks "if it would not be better to discontinue the name Aymestry Limestone as a division altogether, and to call all the beds between the Upper Ludlow and the Wenlock simply Lower Ludlow, though still colouring the thick calcareous beds as before." Now, as in my original classification it was specially explained, and repeated in editions of 'Siluria,' that the term Aymestry or Ludlow Limestone had reference only to limited tracts of England, and was inapplicable to other wide tracts, whether at home or abroad, where the Ludlow-Rock formation has no such subordinate band, it seems to me that Mr. Lightbody's view is quite in unison with my own. See Quart. Journ. Geol. Soc. vol. xix. p. 369.

† See Sil. Syst. p. 201.

whether I look to the information I derived from his fieldwork or to the organic remains with which he liberally supplied me, I have every reason to style Mr. Lewis (as I did in the Preface to the first edition) "my most efficient coadjutor in all the regions of Siluria."

The Aymestry limestone is a subcrystalline earthy rock, arranged in beds from one to five feet thick, the laminæ of deposit being marked by layers of Shells and Corals. In the escarpment of the south-western limb of the Ludlow promontory, this rock frequently forms bluff cliffs, the inclined strata of which, as seen in the centre of the preceding woodcut, rest upon the Lower Ludlow shale, and plunge under the Upper Ludlow rock.

When cut into, the rock is of indigo or bluish-grey colour, in parts mottled by the mixture of white calcareous spar. The quarries, like those in all the harder bands of the Ludlow formation, present, as in the above diagram, natural backs or divisions, usually coated by a dirty-yellow or greenish shale. These are the faces of joints more or less vertical; and, when open, they occasion the rock to separate into rhomboidal masses, which are easily detached if the strata are much inclined. The rock is therefore subject to slides or subsidences, particularly where the underlying saponaceous 'Walker's' or 'fuller's earth' prevails. Examples of these

THE PALMER'S CAIRN LANDSLIP.

(From Sil. Syst. p. 248. Drawn by the late Rev. W. R. Evans.)

The woodcut exhibits the slope of the beds and the vertical joints, which, in conjunction with the lines of bedding, divide the rock into lozenge-shaped blocks.

slides may be seen at many spots, but at no locality more instructively than at the Palmer's Cairn or Churn Bank, S.W. of Ludlow, represented in the foregoing woodcut. The area there affected exceeds fifty acres.

This limestone often occupies the summit or capping of the escarpment

of Ludlow rocks, as in the ridges of Mary Knoll and Brindgwood Chase west of Ludlow,—and in the hills extending from the View Edge and Norton Camp, where it forms a conspicuous band parallel to, and loftier than, the Wenlock Edge (see woodcut, p. 124).

At Aymestry the limestone occupies both banks in the gorge of the River Lugg; but, as above said, it rapidly thins out to the south-west. On the whole it has much less of a concretionary structure than the subjacent Wenlock limestone, and partakes more of the flat-bedded character which is observable in the 'pendle' beneath and distinguishes, indeed, all parts of the Ludlow formation.

In the old quarries at Aymestry it is conspicuously marked by the lines of cavities whence its numerous Corals have been weathered out.

In the Woolhope valley of elevation, the Aymestry rock (see section, p. 110) assumes precisely the same external or physical features as on the flanks of the Ludlow promontory, having from its hardness resisted denudation better than other portions of the deposit. It thus forms the crest of the external and encircling ridge, and is prominent in the hills of Marden, Seager, and Backbury. Although it differs in being a less pure limestone than that near Ludlow, it contains many of the same fossils, even the Pentamerus Knightii, its most characteristic shell (Pl. XXI. f. 10), having been found in the Woolhope district since the 'Silurian System' was published.

On the outermost western slopes of the Malvern Hills, and on the sides and summits of their northern prolongation the Abberley Hills, the Aymestry rock, though containing less calcareous matter than in Shropshire, is still the well-defined central portion of the Ludlow formation. In some of these tracts (as near the Hundred House) it might be used for lime, if the Wenlock limestone, of such superior quality, were not in close proximity. In the districts of May Hill, Usk, &c. this limestone is simply represented by the harder and slightly calcareous central part of the Ludlow rocks.

At Sedgeley, in Staffordshire, the rock becomes once more a useful limestone, in which the predominant Aymestry fossil, Pentamerus Knightii, abounds. There it is known as the 'black limestone,' in contradistinction to that of Dudley, on which, with some intermediate shale or 'bavin,' it reposes*.

The fossils which pervade the Aymestry limestone, in addition to Pentamerus Knightii, are Rhynchonella Wilsoni, Lingula Lewisii, Strophomena euglypha, and large specimens of Atrypa reticularis, Bellerophon dilatatus, Pterinea Sowerbyi, &c., and many of the same Shells, Corals, and Trilobites which are common in the subjacent Wenlock limestone. Indeed, except in the less number of species, and the occurrence of some of

* See 'Silurian System,' sections, p. 481 *et seq.* The Rev. T. T. Lewis first called my attention to the fact of the Sedgeley limestone being the equivalent of the Aymestry rock.

the Shells more characteristic of the next member (the Upper Ludlow rock), this limestone is not greatly distinguished by its fossil contents from the Wenlock limestone.

In some tracts, as at Usk, Monmouthshire, the place of this rock is marked only by the shelly courses which near Ludlow form its immediate cover; and wherever these peculiar beds occur, they are replete with Rhynchonella navicula (Pl. XXII. f. 12) and the small Leptæna lævigata *. It is this band which forms the base of the Upper Ludlow rock; and it may be well seen in the quarries at Aymestry.

Upper Ludlow Rock.—This is the most diversified, in structure and contents, of the three subdivisions of the highest Silurian formation, and is also remarkable in exhibiting a transition into the next overlying system, the Old Red or Devonian. Its lowest stratum is the calcareous shelly band, charged with Rhynchonella navicula, which has just been mentioned as forming the roof of the Aymestry limestone, and which occasionally attains a thickness of 30 or 40 feet. This is surmounted by grey, calcareo-argillaceous masses, so common throughout the Silurian rocks, and which, from their incoherent nature, easily decompose into mud. Like other Silurian sediments of higher antiquity, this mudstone has a tendency to run into large spheroids, and occasionally contains small concretions of sandy clay, which, being more destructible than the pure argillaceous matrix, weather out in the faces of the escarpments, marking the lines of stratification by small elliptic cavities like swallow-holes.

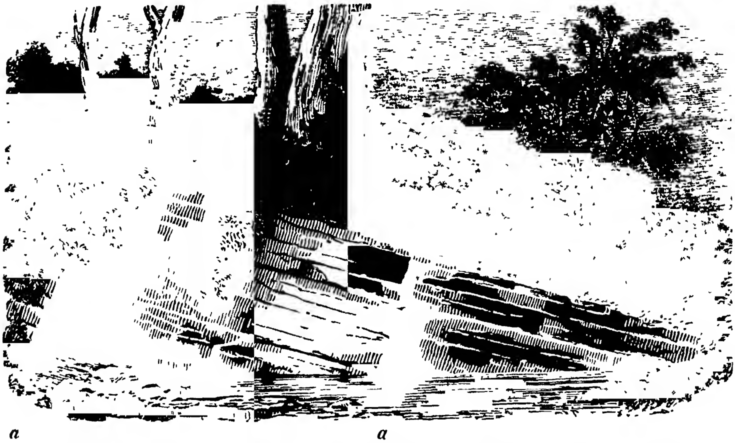
The chief and distinguishing portion of the Upper Ludlow contains more calcareous matter and sand than the beds immediately beneath. It is, on the whole, a slightly micaceous, thin-bedded stone, of bluish-grey colour within, but weathering externally to a brown, rusty grey, and remarkable for its symmetrical, transverse joints, as exhibited at *a*, *a* in the following view (p. 132).

Some strata of this character appear also in the foreground of the vignette, p. 123, which represents the Castle of Ludlow standing on the rock out of which it was built. Though quarried extensively for use, the stones, either when not well selected, or not placed horizontally in the wall in the direction of the layers, are very prone to decomposition. This rock is also well exhibited near Ledbury.

I have elsewhere compared this member of the Upper Ludlow with the 'Macigno' of Italy, and particularly with those dark-greyish portions of the latter which occur between Perugia and Florence. This lithological resemblance of so old a rock to so young a deposit (for the Italian Macigno is no older than the London Clay) is cited to show how similar materials —sand, mud, and calcareous matter, collected on a sea-bottom, often necessarily resemble each other when formed into stone, though originally deposited at such very widely separated periods. In this comparison it is

* Mem. Geol. Surv. vol. ii. pt. 1. pl. 26. fig. 3 (L. lepisma).

further to be noted that the 'Macigno,' or young Italian rock, is infinitely more hard, compact, and durable than the very ancient stone of Ludlow!*



UPPER LUDLOW ROCKS AT THE BONE WELL†. (From Sil. Syst. p. 250.)

The surfaces of these Upper Ludlow rocks are occasionally covered by small wavy ridges and furrows, here and there crossed by little, tortuous, raised bands; the former of these resulted from the rippling action of waves when the sediment was accumulating under a shallow sea, and the latter are the traces left by worm-like or other animals on a sandy and muddy shore during the intervals of the tides.

It is chiefly in this upper portion of the formation that the best-defined organic remains are found, often preserving the sharpness of their forms, and the remains of their original shelly coverings.

Here we meet with a profusion of the following fossils:—Chonetes lata, Pl. XX. f. 8; Orthonota amygdalina, Pl. XXIII. f. 7; Goniophora cymbæformis, f. 2; Pterinea lineatula, f. 16; P. retroflexa, f. 17; Discina rugata, Pl. XX. f. 1, 2; Orthis elegantula (var. orbicularis), f. 9; O. lunata, f. 11; Rhynchonella nucula, Pl. XXII. f. 1, 2; Cyclonema corallii, Pl. XXIV. f. 1; C. Octavia, f. 4; &c.; and the curved shelly Annelide-tube, Serpulites longissimus, Pl. XVI. f. 1. Cornulites serpularius, Pl. XVI. f. 3–9, and a small Tentaculite, f. 12, with the minute Beyrichia Wilckensiana, Pl. XXXIV. f. 21, and B. Klœdeni (Foss. 63. f. 4), are also not uncommon.

Corals are rather scarce; yet Alveolites fibrosus is found frequently incrusting particular species of shells,—Cyclonema corallii and Murchisonia corallii, Pl. XXIV. f. 1 & 7, as their names imply, being its favourite habitats. This Coral has been figured, p. 119 (Foss. 18. f. 8).

* See a description of the Tertiary Macigno of Italy, in my Memoir 'on the Alps, Apennines, and Carpathians,' Quart. Journ. Geol. Soc. vol. v. p. 280.

† This well is so named because bones of mice, frogs, and other small animals are from time to time washed out from the open joints (*a*) of the impending rock. Old Drayton, in his Polyolbion, considered this a great marvel, and converted the bones of frogs into those of fishes:—

"With strange and sundry tales
Of all their wondrous things; and, not the least in Wales,
Of that prodigious spring (him neighbouring as he past)
That *little fishes'* bones continually doth cast."

Orthocerata, occasionally of large size, occur, the species being the same as those known also in the Lower Ludlow rock, Pl. XXVI. *et seq.* O. bullatum abounds. Of Trilobites, Phacops caudatus and Encrinurus punctatus, with a rare sample of the Calymene Blumenbachii, reach the summit; but they are not abundant. The most prevalent Trilobite is a fine species of the genus Homalonotus (H. Knightii, Pl. XIX. f. 7), which may be found throughout the whole range of this formation, from Pembrokeshire to Westmoreland, and is sometimes of very large size.

In the cliffs at Ludlow, the chief body of rock is surmounted by what has been termed the Fucoid-bed. This is a greenish-grey, argillaceous sandstone, almost entirely made up of a multitude of small, wavy, cylindrical, stem-like forms which resemble entangled Sea-weeds. In this mass is found, and always in a vertical position, the singular body (Pl. XII. f. 5) named Cophinus dubius. It is generally of an inversely pyramidal shape, and its sides are scored with elegant transverse grooves. I am assured by Messrs. J. De C. Sowerby and Salter, who have studied it attentively, that it is the impression made by the stems of Encrinites, which, rooted and half-buried in the micaceous mud, have produced, by their wavy and somewhat rotatory motion, the beautiful pattern, every line of which answers to one of the projecting bosses or rings of the jointed stem. In fact these stems are always found lying contiguous to the markings. Such bodies, in their slow trailings or gyrations, may have probably left accurate impressions, in consequence of the diffusion of small particles of mica in the mud, the flat plates of which, having been drawn into positions parallel to the line of motion, may have impeded the perfect fusion of the separated portions of the semifluid mass after the stem had passed through them.

The highest member of the Ludlow rocks is most interesting, inasmuch as until recently it was described by myself as being the oldest rock in which fossil Fishes had been found. The only exception is that already alluded to—the occurrence of a fragment of Pteraspis in the central part of this same formation. The uppermost Ludlow rock also contains the earliest remains of Land Plants (see pp. 135, 138). The lower layers of this zone, as seen at Ludlow, are finely laminated, earthy, greenish-grey sandstones, containing a few Ichthyolites, with several shelly remains characteristic of the formation. It was the middle part only of this band, or a gingerbread-coloured layer of a thickness of three or four inches, and dwindling away to a quarter of an inch, which exhibited, when my attention was first directed to it *, a matted mass of bony fragments, for the most part of small size and of very peculiar character. These, with a few remains of Shells and Crustaceans, including Pterygotus problematicus, occur in a cement in which varying proportions of carbonate of lime, phosphate of lime, iron-oxide, and bitumen are disseminated. Some of the fragments of Fish are of a mahogany hue; but others are of so brilliant a black that, when first discovered, they conveyed the impression

* This course was discovered by my friends and excellent Ludlow coadjutors, the Rev. T. T. Lewis and Dr. Lloyd, both now, alas! removed by death. By their assistance, and that of the late Rev. W. R. Evans, I traced this fish-bed in several other parts of the Ludlow promontory. See Sil. Syst. pp. 198, 605. Mr. Evans showed great sagacity and talent in selecting all the forms which might be considered to pertain to Fishes. These he affixed to tablets, which I believed to have been deposited with the original Silurian types presented by myself to the Museum of the Geological Society; but, unluckily, these unique and precious forms, so carefully drawn by Mr. James De C. Sowerby, and described by Agassiz (see Pl. XXXV.), can now nowhere be found.

that the bed was a heap of broken beetles. Dr. Harley has truly remarked* that this bed is often very compact, and of a lighter colour, and closely resembles the cake from which linseed-oil has been expressed.

The supposed Fishes of this stratum, as exhibited in my original work, must now, it seems, be reduced in number. At all events, besides the remarkable Pterygotus, portions of which are figured in Pl. XIX. f. 4–6, and which was removed by Agassiz himself to the class of Crustaceans, Professor M'Coy has diminished the list of Ichthyolite remains by proving that some of the supposed fish-defences should also be removed to that group. One of these, to which he has applied the name Leptocheles Murchisoni (see Pl. XIX. f. 1, 2), was formerly figured as an Onchus, or fish-defence †. But although these may be removed from our scanty list of Upper Silurian vertebrata, the ichthyic nature of several specimens figured in Pl. XXXV. figs 1–18, is evident from their external characters, and has been proved satisfactorily by the microscopic researches of Dr. Harley, who has also discriminated numerous minute Crustacean organisms, including Conodonts, in the Bone-bed. (See Chap. X.)

The capping of the Bone-bed is composed of light-coloured, thin-bedded, slightly micaceous sandstones, in which quarries are opened out near Downton Castle on the Teme (the Downton-Castle stone, Sil. Syst. p. 197). It is traceable also in the vicinity of Malvern.

The uppermost layers of the whole Silurian system, and which form a transition into the Old Red Sandstone, consist of thin-bedded flagstones, occasionally reddish, and in certain districts forming 'Tilestones:' these contain Lingula cornea (Pl. XXXIV. f. 2, a fossil found in the Ludlow rock), with Crustaceans, fin-rays of Fishes, and remains of the singular fish Pteraspis (Pl. XXXVI. f. 9, 10, 11).

Being compelled in my earlier researches to draw a line of demarcation between the Upper Ludlow formation and the bottom of the overlying Old Red Sandstone, I then included the tilestones in the latter,—particularly as in most parts of the region a portion of them decomposes into a red soil, thus affording a clear physical line of demarcation between them and the inferior grey rocks ‡. The fossils which were then figured as characteristic of such tilestones exhibited little else than species common to the Upper Ludlow rock, and were chiefly obtained from this formation as it ranges through Clun Forest and some parts of South Wales, where the Bone-bed has not yet been seen. These species and others since discovered have, indeed, for seventeen years led me to classify these tilestones with the Silurian rocks, of which they form the natural summit. For, in their

* Quart. Journ. Geol. Soc. vol. xvii. p. 543.

† For further illustration of this point, see Quart. Journ. Geol. Soc. Lond. vol. ix. p. 12; and vol. xvii. p. 545.

‡ The reader who may refer to my original map must recollect that it was constructed between the years 1831 and 1836. At that time I coloured such sheets of the Trigonometrical Survey as had been published; and from those and other rude materials my map was constructed. In fact nearly all the country of Wales to the west of my typical region was then undefined upon accurate maps. Geologists who have had to labour with imperfect topographical assistance in a region which, like this, had been wholly unexplored by miners, are not those who will criticise errors of detail, which have been remedied by those who followed me. The classification and chief outlines of my map and sections, as far as they relate to my own Silurian rocks, have indeed, in all essential points, been sanctioned by the Geological Survey and the numerous geologists, led by Professor Phillips, who have succeeded me.

range from Shropshire, through Herefordshire, Radnor, Brecon, and Carmarthen, where they are often of red and yellowish colours, they are charged with Orthoceras bullatum, Chonetes lata, Spirifer elevatus, Orthis lunata, Rhynchonella nucula, Cucullella? ovata, Bellerophon trilobatus, B. expansus, Platychisma helicites, Holopella obsoleta (see Pl. XXXIV.), and the minute bivalved Crustacean, Beyrichia Klœdeni (Foss. 64. f. 4). All of these are common fossils of the Upper Ludlow rock; and a few of them are found as low even as the Upper Llandovery rock beneath the Wenlock shale.

If we include the Downton Castle building-stone, this transition-band contains the oldest casts of recognizable terrestrial vegetation yet found in England and Wales*. The specimens hitherto collected are usually small, and little more than carbonized fragments. At the bottom of the detached basin of Old Red Sandstone of Clun Forest in Shropshire, I detected thin layers of matted and broken vegetables (frequently carbonized) in the 'tilestone' and 'firestone' beds of that tract (Sil. Syst. p. 191). Since then our acquaintance with them has been enlarged; and the Museum in Jermyn Street contains many more specimens from this stratum, among which are the minute globular bodies, Pl. XXXV. f. 30, called 'Bufonites' in the 'Silurian System,' but which, as will presently be explained, are now known to be of vegetable origin.

Though not everywhere divisible into the portions above described, the Upper Ludlow rock maintains, on the whole, a decisive aspect in its range through Shropshire, Hereford, and Radnor into Brecknock and Carmarthenshire, until last seen in the cliffs of Marloes Bay, Pembrokeshire. Frequently somewhat calcareous, the deposit is in these districts for the most part a harder and more sandy stone, partaking in a greater degree of the character of the Italian 'Macigno,' as before said, than any other rock of the Silurian system. Sometimes it is even a hard siliceous rock.

On the eastward slopes of Bradnor and Hergest Hills, near Kington, and particularly in the ridges extending thence by Gladestry and Pains Castle to the Treweme Hills on the Wye, this formation is often admirably exposed in slightly inclined masses replete with fossils. In the escarpment of the Trewerne and Begwm Hills †, and in many other places, it is strikingly exhibited as a grey, shelly, thin-bedded rock, dipping under the bottom beds of the Old Red Sandstone, as in the woodcuts, pp. 110, 124, 137.

Along the outer or western edge of the Malvern Hills, the section of the Upper and Lower Silurian rocks, as illustrated at p. 95, exhibits, in like manner, Upper Ludlow rocks dipping under the Old Red. Descriptions of this subformation, as occurring at many places, from Ledbury northwards,

* Some traces of large Plants, possibly of land growth, occur in the Upper Silurian rocks of the Eastern Harz, near Mägdesprung.

† This was my first Silurian section, 1831, in passing from the *known* Old Red to the then *unknown* Ludlow rocks, Sil. Syst. pp. 5, 312.

may be consulted both in the 'Silurian System' and in Professor Phillips's monograph *.

A very remarkable section of the Passage-beds from the Upper Silurian Rocks into the Lower Old Red Sandstone has been laid open on the line of Railway between Worcester and Hereford, near the town of Ledbury. It was described by the Rev. W. S. Symonds, in full detail, in the Quarterly Journal of the Geological Society, vol. xvi. p. 194; and vol. xvii. p. 152 &c. The section was more perfect than that at Ludlow, not being interfered with by any break in the strata. The Aymestry rock (with Pentamerus Knightii) occurred in the Ledbury tunnel; and the rocks in ascending order to the point opposite the Ledbury Station furnish the following series of strata and fossils:—1. Aymestry rock (10 feet). 2. Upper Ludlow rock with Chonetes lata &c. (140 feet); Ludlow bone-layer not detected. 3. Downton sandstone with the characteristic Lingula; 9 feet. 4. Red and mottled marls and thin sandstones, with Lingulæ and remains of Pteraspis; 210 feet. 5. Grey shales and grit at the entrance of the tunnel, with Cephalaspis Murchisoni and Pterygotus; 8 feet. 6. Purple shales and thin sandstones (34 feet). 7. Grey marl passing into red and grey marl and bluish-grey rock (Auchenaspis-grits), with Auchenaspis, Plectrodus, Cephalaspis (two species), Onchus, Pterygotus, a Lituite, and Lingula; 20 feet. These strata pass conformably upwards into a series of red marls, with grey and reddish sandstone, in which Henry Brooks, the geological shoemaker of Ledbury, found the remains of Pteraspis and Cephalaspis. It was owing to his persevering labour that Mr. Symonds was happily enabled to correlate these beds with their equivalents near Ludlow. It was thus found that fossils diminish as soon as the horizon of the Upper Ludlow rocks is passed; but, according to Mr. Salter, the Lingula of the Downton beds is the same as that found at the base of the Old Red. Again, there is little doubt that the Pteraspis of the Bone-bed ascends into the Lower Old Red, where it is associated with Cephalaspidian Fishes. Whilst it is difficult to define with minute accuracy the line which separates the lower system from the upper, it is clear that the Ledbury section proves the value of the term 'Passage-beds' even more fully than the sections near Ludlow, Kington, &c.

Similar passages upwards, from inferior grey-coloured to superior red rocks, are observable at Usk and in tracts around that town, where the Ludlow rocks rest upon Wenlock limestone † and are full of the ordinary fossils. This small Silurian oasis in a region of Old Red Sandstone (see Map) is highly interesting, and exhibits on either bank of the River Usk some peculiarities of mineral structure connecting the eastern and western tracts of the Silurian region.

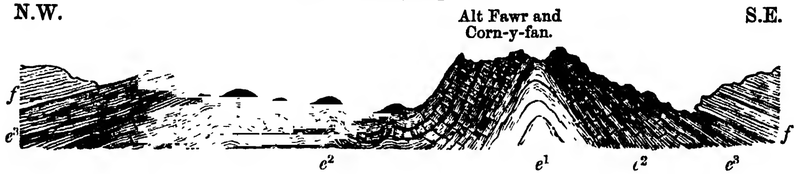
In Brecknockshire, to the south of Builth, the Ludlow rocks, surmounting a noble escarpment of the lower member of the Upper Silurian on the

* Mem. Geol. Surv. Great Brit. vol. ii. part 1.

† Sil. Syst. p. 408.

right bank of the Wye, but in which no limestone occurs, exhibit a fine upward development, as they pass under the Old Red Sandstone in the wilds of Mynydd Epynt (see the long vignette, p. 58, and Chapter XI.). There the Upper Ludlow rises from beneath the Old Red, in a rapid anticlinal flexure at Alt-fawr and Corn-y-fan, as here represented, the central

BRECON ANTICLINAL OF LUDLOW ROCKS, THROWING OFF OLD RED SANDSTONE.
(From Sil. Syst. p. 211.)



*e*1. Lower Ludlow. *e*2. Middle Ludlow, with a calcareous band representing the Aymestry limestone. *e*3. Upper Ludlow. *f.* Old Red (lowest beds).

and lower members of the formation forming the underlying, arched, untinted strata, *e*1.

Thence into Carmarthenshire, the junction of the Ludlow rocks with the Old Red Sandstone is well laid open in numerous places, especially in the narrow valley of Cwm Dwr, between Trecastle and Llandovery, where the Tilestones, on which Horeb Chapel stands, are full of the casts of Shells, among which are characteristic forms, such as the Platychisma helicites, Pl. Williamsi, Bellerophon trilobatus, and many others.

The banks of the River Sawdde, in Carmarthenshire, east of Llangadock, also expose a good junction of these highly micaceous Upper Silurian flagstones with overlying Old Red marl, the whole at very high angles of inclination. Thence, in its range to the mouth of the Towy, the Upper Ludlow becomes a compact hard sandstone, everywhere surmounted by Old Red *.

In Pembrokeshire, similar junctions with the Old Red Sandstone are seen near Tavern Spite, Narberth, at Freshwater East and West, and in Marloes Bay. In all these places, strata of dull greenish-grey argillaceous sandstone, minutely micaceous, differing from the type of the Upper Ludlow of Shropshire in being harder and thicker-bedded, repose on rocks with Upper Silurian fossils, and plunge under red and green strata (the 'red rab' of Pembroke), or bottom beds of the Old Red Sandstone.

In the Valley of Woolhope, particularly in Backbury Camp, Seager Hill, and in the transverse gorges or hollows locally called 'Cock-shoots,' the same succession is very apparent all round the external rim of that remarkable elliptical elevation (see diagram, p. 110). In nearly all parts of that boundary, the Upper Ludlow is well exposed in its characteristic lithological condition, and is copiously charged with its prevalent fossils, Chonetes

* See woodcuts, pp. 55, 56.

lata &c., Pl. XX. *et seq.* It even contains, in one or two spots, the remains of Fishes.

At Hagley Park, distant only two miles from the north-western end of the Woolhope ellipse, and four miles east of Hereford, the uppermost beds of the Ludlow formation have been exposed from beneath their cover of red clay and marl; and there the thin bed containing Fish-bones and the Crustacean Pterygotus was found by Mr. H. Strickland to be just in the same relative position as at Ludlow *. This spot marks a minor undulation, or dome, of Ludlow rock, the surface of which only is visible: a much greater mass of the formation has been protruded in the adjacent hill of Shucknall, as formerly described (Sil. Syst.). At Hagley Park the Fish-bed, scarcely exceeding an inch in thickness, lies between strata of brownish and yellowish sandstone (the Downton Castle stone) and a grey micaceous shale full of Upper Ludlow fossils. The Fish-remains are chiefly those of the minute shagreen scales (Pl. XXXV. f. 18), the fin-rays Onchus Murchisoni and O. tenuistriatus (figs. 13–17), with coprolites (figs. 21–28). In the sandy beds above these there are the carbonized remains of vegetables; and among them Mr. Strickland detected some of the minute globular bodies mentioned before, which Dr. Hooker has ascertained to be seed-vessels belonging to Plants of the order Lycopodiaceæ †. Similar vegetable traces have been observed at various places around the external rim of the Woolhope ellipse, as near Stoke Edith &c.

Since the publication of the first edition of this work, the Bone-bed has been discovered at Brockhill, by the late Rev. F. Dyson, and by Mr. Salter at Hales End, both near Malvern, where it is a calcareous layer, full of common Ludlow shells, and overlain by Downton sandstone.

Again, in the southernmost prolongation of the Silurian group of May Hill and Huntley Hill, where I formerly described the whole Silurian series as reduced to one thin mass of Ludlow rock, having the Old Red Sandstone on one side, and the New Red on the other, my lamented friend Mr. Hugh Strickland detected one of these thin layers of Fish-bones in precisely the same position as at Ludlow.

In the arched or dome-shaped masses of Upper Silurian rocks which rise out from beneath the Old Red Sandstone at Pyrton Passage on the Severn, Professor Phillips has also noted the remains of small Fish-bones in the Upper Ludlow rocks ‡.

Recognizing the original Bone-bed of the Ludlow rock on the face of Bradnor Hill near Kington, Mr Richard Banks has shown that it is there overlain by liver-coloured strata containing Chonetes lata, Orthonota

* I visited the spot since the discovery, in company with Mr. Strickland. See his descriptions of these beds in the south of Herefordshire and in Gloucestershire: Quart. Journ. Geol. Soc. Lond. vol. viii. p. 381, and ib. vol. ix. p. 8.

† These seed-vessels or spore-cases are now known by the name Pachytheca sphærica, Hooker: Quart. Journ. Geol. Soc. vol. xvii. p. 162.

‡ Mem. Geol. Surv. of Great Brit. vol. ii. part 1. The succession of the Silurian rocks in the dislocated tract of Tortworth, to the S.E. of Pyrton Passage, is described in detail in the 'Silurian System,' p. 99.

§ Formerly known as Trochus helicites.

amygdalina, &c.; a bed charged with Platyschisma helicites and Lingula cornea then occurs, followed by other strata of somewhat different mineral character, containing the remains of Fishes and their coprolites, with the peculiar Crustacean Pterygotus, &c.*

The lowest of these overlying beds, as seen in the quarries towards the summit of Bradnor Hill, north of Kington, is a greyish and yellowish band, containing Platyschisma helicites, together with a species of Modiolopsis, and Beyrichia Klœdeni, fossils which have been considered characteristic of the Upper Ludlow rock†. This is followed by a thin layer of flaglike sandstone with many species of Onchus and the Lingula cornea. This thin layer, and another which is charged with fragments of Pterygoti and two species of Ichthyolites (Pteraspis), are surmounted by the bluish or light-grey, hard building-stone of Kington. This, again, is covered by less massive beds (also charged with the same Crustaceans and Fishes, together with fragments of carbonized Plants) that graduate insensibly into more micaceous and thin-splitting layers, formerly used as tiles. Now all these strata constitute the regular summit of the range of the Kington Hills, the soil of which is nowhere red, though, in following them in their gradual inclination to the south-east, into the lower grounds of Herefordshire, on the banks of the River Arrow, they are seen to be covered by red marls and sandstone.

In the environs of Ludlow, remains of Fishes and Crustaceans in beds at a higher level than the original Bone-bed have also been detected, chiefly through the close researches of Mr. Lightbody. In the railroad-cutting north-east of Ludlow, a small insulated portion of an olive- or grey-coloured shale was exposed‡. It is faulted on the north-west against Old Red Sandstone, and is conformably surmounted on the south-east by red marls &c. The lowest visible layer at this spot is a finely levigated, liver-coloured and greyish rock in which certain Ichthyolites and other fossils occur; and this passes upwards into an overlying reddish-brown micaceous sandstone, which in its turn graduates into red shale or marl. It is manifest, therefore, that this member is distinct from, and superior to, the first-described Ludlow Bone-bed (Sil. Syst. p. 198), since that stratum is fairly overlain by grey rocks and the Downton Castle building-stone. In the beds at the railroad there have been found fragments of Plectrodus and the Onchus Murchisoni, as well as Lingula cornea and Beyrichia Klœdeni,

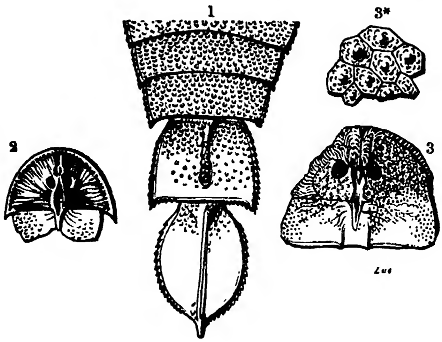
* Quart. Journ. Geol. Soc. vol. xii. p. 93. That these Kington rocks contain Coprolites similar to those described from Ludlow has been determined by the analysis of Dr. Hofmann, late of the Government School of Mines, who found that these bodies consist chiefly of phosphate of lime with small quantities of phosphate of magnesia, silicate of alumina, and sulphate of lime, with traces of sesquioxide of iron, oxide of manganese, chloride of sodium, and organic matter. There are also in these rocks, extending from Kington to the south-west, perfectly round nodules, chiefly of iron-pyrites with a siliceous matrix.

† When examining the beds at Kington in company with Prof. Ramsay and Mr. Aveline, I was much gratified in looking through the valuable collection, made by Mr. Banks, of the fossils of the Ludlow rocks and the beds forming their natural capping. The Ludlow bone-beds discovered by Mr. Lightbody were also visited by us, with Mr. Salter, who identified most of the fossils *in situ*, and who found that the Pterygoti which occur in this stratum were of several distinct species. A Monograph, by Huxley and Salter, descriptive of these fossils, forms part of the Memoirs of the Geological Survey.

‡ See Quart. Journ. Geol. Soc. Lond. vol. xix. p. 290.

found in the lower bone-bed. On the other hand, the following species here found are unknown in any inferior stratum, namely:—Cephalaspis? ornatus, Egerton; Auchenaspis Salteri †, Eg.; Pterygotus Ludensis, Salter; Eurypterus pygmæus, Salter.

FOSSILS (22). CRUSTACEAN AND FISHES FROM THE PASSAGE-BEDS, LUDLOW.



1. Pterygotus Ludensis, Salter; the caudal portion, much reduced in size.
2. Auchenaspis Salteri, Egerton. Head-shield.
3. Cephalaspis? ornatus, Egerton. (An imperfect head-shield; half the natural size.)
3*. Portion of fig. 3, magnified.

Besides the portion here figured of the gigantic Crustacean Pterygotus Ludensis, its pincers and other parts have been collected at this spot. Mr. Salter concludes that this giant of the Crustacea measured not less than seven or eight feet in length, and had a proportionate breadth and thickness. Some further details of its structure will be given in Chapter X.

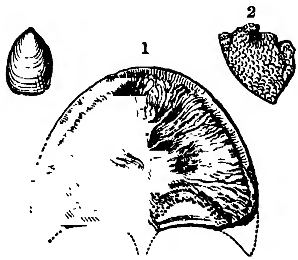
On the right bank of the River Teme, opposite Ludlow, a clearer ascending succession of strata has been traced, notwithstanding a heavy cover of drift and gravel, and chiefly by observing the strata which appear when the river is very low. Thus the rocks containing the original Bone-bed are observed to slope gently down to the south-east, and to pass under light-coloured flagstones, which at the Corn-mill near Ludford are overlain by micaceous brownish sandstone. These, again, are followed by reddish marls with greenish minute concretions. Whether the same Fish-bed which is observable at the Railroad may not be detected at this point is uncertain, as the series is irregularly traceable only ‡. But above all these strata, both grey and red, there occurs a band of light-grey micaceous sandstone or grit with carbonaceous markings and spore-cases of cryptogamic Plants, and in it Mr. Lightbody has detected remains of Fishes and other fossils. Among these we again find the Plectrodus mirabilis, Onchus Murchisoni, and Lingula cornea of the lower Bone-bed, though the Platyschisma helicites of that horizon is no longer detected. It may therefore be naturally suggested that this band constitutes the last link in the chain of Silurian life.

† Auchenaspis differs from Cephalaspis in having the buckler truncated behind, and the nape of the neck covered by two wide square plates with granular surfaces—a character not found in the broad lunate heads of Fishes so common in the Old Red Sandstone of Scotland and Herefordshire.

‡ It is manifest that faults must abound near the apex of the elevated Ludlow promontory, and that dislocations similar to that which occurs at the Railroad may be frequent.

In this rock there is, indeed, a form of Fish not yet seen in the inferior courses, to which Sir P. Egerton assigned in 1857 the name of Cephalaspis

FOSSILS (23) OF THE UPPERMOST BONE-BED, NEAR LUDLOW.



1. Cephalaspis Murchisoni, Egerton. Inside of head-shield. Less than half the natural size.

2. Pterygotus; fragment of foot.
3. Lingula cornea, Sil. Syst.

Murchisoni (Quart. Journ. Geol. Soc. vol. xiii. p. 284). It is represented in the preceding woodcut; and differing, as it does, in a marked manner, by the truncated, not arched, posterior margin, from Cephalaspis Lyellii of the Old Red Sandstone, this species may be regarded as characteristic of a bed which indicates a true passage from the summit of the Silurian rocks into the Devonian rocks or Old Red Sandstone. In the copious development of red marls and thick-bedded sandstones which follows, the fossils that characterize the inferior strata are no longer detected.

Another example of the ascending order from the mass of the Upper Ludlow rock, through the chief bone-bed, into the overlying Downton Castle building-stone, has been detected by Mr. Alfred Marston, near Norton, on the road to Onibury, where the fish-bed, six inches thick, is surmounted by a thin course charged with Pterygoti, and covered by argillaceous layers (replete with Platychisma helicites and Beyrichia Klœdeni) which form the base of the Downton Castle sandstone. Mr. Lightbody has observed a similar succession at the north side of Whitcliffe Coppice, near Ludlow, as well as in the section shown by the Ludlow Railway-cutting.

The persistence of the uppermost band of the Ludlow rock, with its land-plants, fishes, and the same species of shells, at considerable distances from the tract in which it was first described, is truly remarkable, and shows the value of close and minute researches over extensive areas.

The Tilestones or Passage-beds are visible all along the eastern frontier of the Silurian rocks (particularly from Kington to the Treweme Hills on the Wye), and scarcely exceed forty or fifty feet of maximum thickness, including both their thick and thin strata and even some reddish marl and micaceous sandstones. They constitute, therefore, both lithologically and zoologically, a true transition, and cannot be arbitrarily classed as a whole either with Silurian or Devonian. It is, however, manifest from

its organic remains that the lowest of the bone-beds is really part and parcel of the Ludlow rock *.

In the next chapter it will, indeed, be seen that large and peculiar species of Crustaceans (Pterygoti) also specially characterize the very uppermost beds of the Silurian rocks of Scotland, or the black slaty shale of Lanarkshire, which clearly underlies every stratum to which the term Old Red Sandstone has been applied. Again, as will afterwards be shown, the same term in the series of the Palæozoic rocks of Russia, viz. grey and calcareous strata underlying all the Devonian rocks, is characterized by Crustaceans of the family of Eurypteridæ; whilst both in Scotland and Russia these Crustaceans are associated with Lingula cornea, an unmistakeable shell of the Upper Ludlow rock.

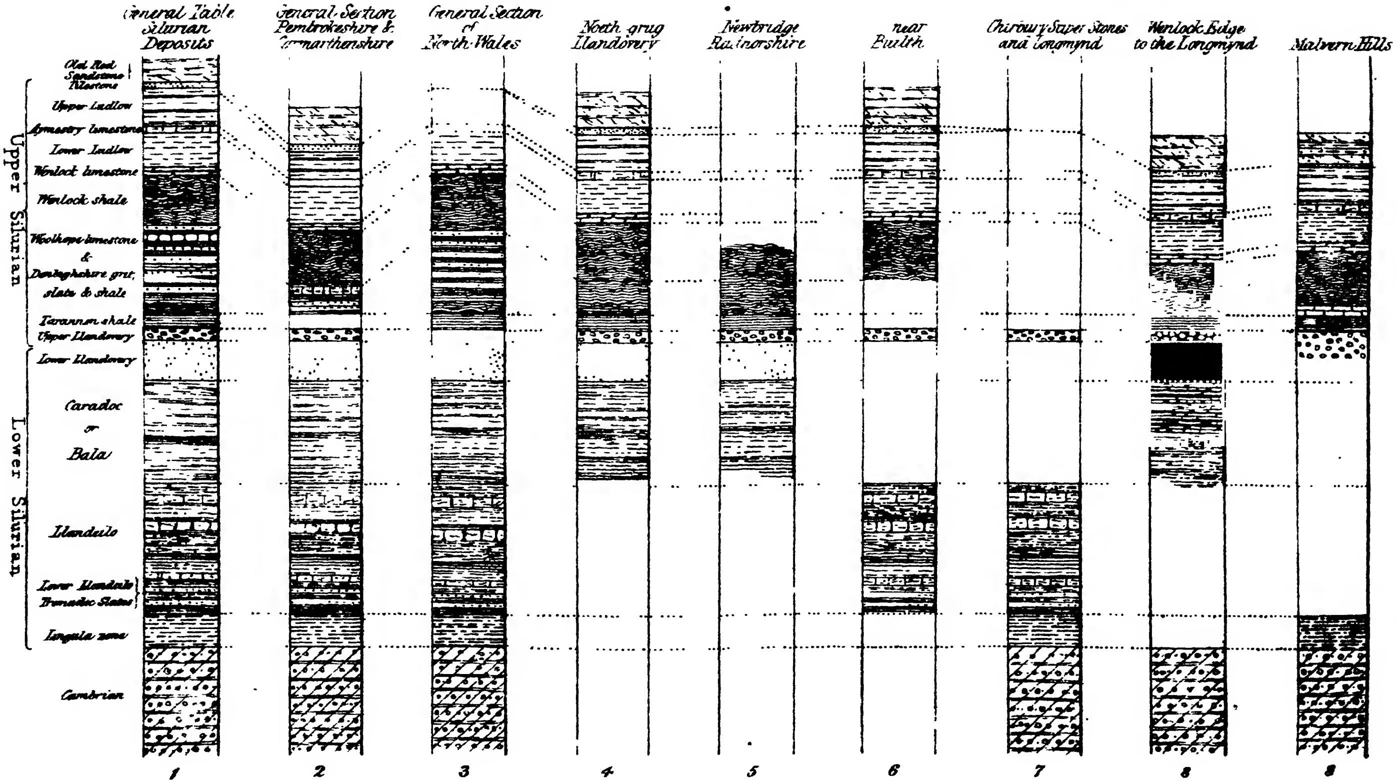
The formations and subdivisions of the Silurian rocks of the region illustrated in the Map having now been described in the greatest detail compatible with the limits of this work, the reader is referred to the accompanying valuable Table of comparison, prepared by Mr. Aveline of the Geological Survey, that he may recognize at one view the varied developments of the strata in different tracts of Wales and the adjacent English counties.

The first of the vertical columns in this Table represents a more complete series than can be seen in any one consecutive natural section. It is a union of all the known strata, as derived from various localities. A near approach, however, to this complete sequence of beds is observable in South Wales, as expressed in the second column, which country, including the neighbourhood of Llandovery (No. 4), together with Shropshire, Herefordshire, and the border Welsh tracts of Montgomery and Radnor (Nos. 5, 6, 7, 8, & 9), constituted the original Silurian region. By observing this comparative view, we mark the attenuation, in some districts, of deposits which are expanded and interpolated in others, also that certain bands well exposed in limited areas are wholly omitted in other tracts. The inquirer has thus before him the condensed results of the long and laborious researches of the Geological Survey in unravelling the highly diversified conditions of the substrata in Wales and Siluria.

In viewing this Table, it is to be recollected that in column No. 8 the ascending order might have been continued through the Ludlow rocks up to the Old Red Sandstone, inasmuch as that succession is everywhere visible to the S.E. of the Wenlock Edge. By combining such an ascending

* Mr. D. Page, in his able Manual, has regarded the original Ludlow bone-bed as part of the Old Red Sandstone. His ground for this classification is, that fossil Fishes here first appear. But I contend that the presence of Plectrodus mirabilis and Onchus Murchisoni (neither of them Old Red Fishes) in the lowest bone-bed affords no reason for separating it from the Ludlow rocks, seeing that this very band is filled with marine Shells unequivocally of Silurian age, many of which are found low down in the system.

COMPARATIVE SECTIONS OF SILURIAN DEPOSITS, by W Talbot Aveline, F.G.S.



section as is seen in No. 1 (and which is everywhere apparent along the Silurian frontier) with the section from the Longmynd to the N.W. (No. 7), in which the lower divisions are fully developed, the geologist has before him, in Shropshire only, the whole Silurian system from its base to its summit, with the exception of the hiatus occasioned by the absence of a portion of the Llandovery Rocks explained at p. 89. In this same limited tract he also sees the most copious development of the Cambrian rocks known in Great Britain (the Longmynd), and finds, in short, nearly all the strata which by great undulations are spread over the Principality of Wales and various English counties!

A complete acquaintance with the numerous great dislocations which occur throughout the Silurian rocks can only be obtained by consulting the maps and sections of the Geological Survey. Reverting for a moment to such phenomena, the reader has only to refer to the section at p. 89 to see that, by the compound fractures of the crust in even the typical Silurian tract of Shropshire, the very oldest known sediments of the region are brought into contact with various overlying rocks. In that diagram, reduced from the Survey Sections, we see, indeed, how different Upper Silurian rocks are broken up and forced in between an upper member of the Lower Silurian and the deep-seated Cambrian rocks of the Longmynd. And yet the geologist has only to follow the undulations of the Lower Silurian strata into Montgomeryshire to find the regular consecutive order reestablished between those rocks and the overlying strata; whilst in parts of Shropshire, Herefordshire, and South Wales the Upper Silurian rocks equally follow a clear ascending order.

In terminating this sketch of the remarkable British Silurian region exhibited in the Map, and leaving the further description of the fossils for separate chapters, the following vignette is introduced, to represent at a

SILURIAN ROCKS OF MARLOES BAY, DIPPING UNDER THE OLD RED SANDSTONE OF HOOK POINT, PEMBROKESHIRE. (From Sil. Syst. p. 392.)

glance the only section on the sea-coast where a large proportion of the

Silurian rocks is seen to dip under the Old Red Sandstone. At the eastern end of St. Bride's Bay, in Pembrokeshire, the Lower Silurian rocks, much dislocated, and associated with those bands of trap which form a striking outline in the Skomer Isles, plunge rapidly to the south-east, and sink under the strata of the mainland; the latter consist chiefly of quartzose and schistose rocks, such as are well seen in Wooltack Pack, associated with much igneous matter.

One of the highest of these broken bands (*c*), representing the Upper Llandovery rock, forms the foreground of Marloes Bay,—the chief cliffs in the landscape being composed of schists and sandstones of considerable dimensions, all highly inclined to the south-east, as expressed in the preceding vignette. The upper portion of these strata (*d*), comprising a few courses of impure limestone, contains the fossils of the Wenlock formation, and is covered by some equivalents of the Ludlow strata, in the condition of hard, siliceous, grey rocks, the whole being overlain in the distance by the Old Red Sandstone (*e*) of Hook Point *.

* In the corner of the accompanying Map, attention is directed to an enlarged portion of this tract, in which the powerful dislocations to which the strata have been subjected are marked.

CHAPTER VIII.

SILURIAN ROCKS OF BRITAIN

BEYOND THE ORIGINAL TYPICAL REGION—NAMELY, IN CORNWALL, THE NORTH-WEST OF ENGLAND, SCOTLAND, AND IRELAND.

THOUGH occupying large spaces in other parts of the British Isles, the Silurian rocks, as separated into formations and characterized by fossils, are nowhere so clearly defined as in the typical portion of the region of which we have taken leave. In no other tract of the United Kingdom have geologists been able to show so clearly the relations of the different members of the lower fossiliferous rocks, nor so clear an ascending order from the Silurian into the next overlying deposit, the Old Red Sandstone or Devonian rocks.

In Cornwall, for example, the discovery of certain fossils has proved that some of the quartzose sandstones forming its southern headlands are Lower Silurian. The fossiliferous sandstone in question, passing to the south of the Dodman, and coming out to view in Gorran Haven, contains several species of Orthidæ, as well as Trilobites, which characterize that division *.

There, however, no one can show an unbroken descending sequence beneath those beds, nor an ascending order from them to the younger deposits of Upper Silurian and Devonian age; and as large portions of the strata of Cornwall have been highly altered and mineralized, so also is this southern tract much dislocated. In such a region, therefore, we cannot expect to meet with proofs of succession. It is sufficient to state that the band of grits and quartzites in the south of Cornwall, which I termed Silurian in 1846, presents much of the character and aspect of the opposite rocks of Cherbourg and Brittany, which the French geologists have mapped and described as Lower Silurian (see Chapter XVII.). This is precisely one of those broken and insulated tracts of older sedimentary rocks where the geologist has no other test by which he can recognize age than their imbedded organic remains.

Professor Sedgwick, who visited the localities after I had described them, shows, indeed, that these strata are inverted, and overlie the Devonian or Old Red rocks. The chief fossils defined by Sedgwick and M'Coy † consist of the simple-plaited Orthidæ so common in the Lower Silurian rocks (Pls. V. & VI.), viz.: Orthis calligramma, O. flabellulum, O. elegantula, and O. testudinaria; Strophomena grandis; and the Trilobites

* These fossils were collected by Mr. Peach; and, from their inspection and a visit to their chief localities in 1846, I termed the rocks in which they occur Lower Silurian (Trans. Roy. Geol. Soc. Cornwall, 1846, p. 317); and as such they were inserted in a new edition of my little Geological Map of England and Wales, published by the Society for the Diffusion of Useful Knowledge.

† See Quart. Journ. Geol. Soc. Lond. vol. viii. p. 13.

Homalonotus bisulcatus, Calymene duplicata ?, and Phacops apiculatus. These are all true Lower Silurian types of the Caradoc formation.

In the north-western and mountainous part of England, the Silurian rocks appear in great force in the counties of Westmoreland and Cumberland and the adjacent tracts of Lancashire and Yorkshire. Though some of the members there assume a lithological aspect different from what they maintain in the Silurian and Welsh region, they have been clearly paralleled by several geologists with those original types. Professor Sedgwick, who has most studied the Lake region (which I have also traversed on five occasions for purposes of general comparison), and who has described it in a series of valuable memoirs, has grouped the lowest fossiliferous limestones, or those of Coniston, with his Cambrian rocks, though during several years he identified them by means of the published fossils with the Lower Silurian and even with its upper portion.

In truth, the region of Siluria, as geologists now admit, afforded the key by which the fossiliferous strata in the north-western tracts of England were brought into order and had their proper places assigned to them. In Cumberland, however, where the lowest members of this series rise up into the lofty mountains of Skiddaw and Saddleback, parts of these masses of schists, though simply of Lower Silurian age, are in the condition of fine, glossy, chiastolite slates.

The lowest of these rocks had afforded no fossils except Graptolites and Fucoids, and were considered by Professor Sedgwick to be of as high an antiquity as the lowest Cambrian beds of North Wales. The researches, however, of Professor Harkness and Mr. Nicholson have ascertained that this is not the case. They have shown that these Skiddaw slates of Cumberland are not even so old as the Lingula-flags of North Wales, but are of Lower Llandeilo age, as proved not only by containing the very same species of Graptolites which occur in that subformation, but also Trilobites, Orthidæ, and other fossils which characterize that zone. In vain, therefore, in such a country has the geologist sought for the equivalents of the bottom rocks, described in the earlier chapters as overlain conformably by strata with Lingulæ and Trilobites. Nowhere in the Lake region have the repeated labours of geologists or fossil-collectors detected the 'primordial zone' of Barrande—or Lingula-flags.

The Skiddaw (or Lower Llandeilo) slates are overlain by vast masses of green slates and porphyries, in which scarcely the trace of a fossil has been found, owing doubtless, in great measure, to a superabundance of igneous matter, which has been still more copiously given out in this Lake region than in the mass of the Llandeilo rocks of the typical region (see above, p. 79). To the south of these lofty and picturesque mountains, we come to the Coniston limestone, with its overlying flagstones. At that zone only do we begin to find a rich fauna; and, judging from the organic

remains, it is clearly a representative of the Caradoc formation of the Lower Silurian rocks. For, among the fossils, the same species of simple-plaited Orthidæ, of Trilobites, and Corals are again met with which characterize the limestones of Bala in North Wales and the shelly sandstones of Caer Caradoc in Shropshire.

In proceeding to the south and south-east from the more mountainous and crystalline part of this north-western tract of England, the Lower Silurian rocks are seen to be succeeded by younger deposits, which, though of very different mineral characters, unquestionably represent by position and fossils the Wenlock and Ludlow formations. I cannot more tersely and clearly express these relations than in the language which Professor Sedgwick himself applied to this region in 1845. "Thus the fossiliferous slates," he says, "present, first, the Lower Silurian rocks in a very degenerate form, and secondly the Upper Silurians in a noble series" *.

Nor can I convey a better idea of the succession of rocks in this district than by referring the reader to sections and descriptions by the same author published in 1846, to be studied in combination with his memoirs of 1851–2. It is enough for me, on this occasion, to state that these show a conformable succession of deposits, from the Skiddaw slates and a vast thickness of green slates and porphyry, to a thin band of limestone (Caradoc or Bala) and a considerable thickness of overlying flagstone with Lower Silurian fossils, followed by the 'Coniston Grits,' which Professor Sedgwick believes to be the equivalent of the May Hill sandstone. They are surmounted by a copious Upper Silurian series, in which the Wenlock and Ludlow formations are recognized by their position and fossils, though, as before said, their mineral aspect differs much from that of the original types.

This Upper Silurian series, forming the ridges on both sides of Windermere, and thence extending far to the south, consists in the lower masses of the Ireleth slates. These masses have a slaty cleavage oblique to the beds, are in parts calcareous, and have proved to be the equivalents of the Wenlock formation, more particularly resembling certain schists in Denbighshire, which also assume a hard, arenaceous, and slaty character. Among other fossils the curious Graptolite, Retiolites Geinitzianus, Barr., found in the Upper Silurian (Étage E) of Bohemia occurs in these slates. The overlying strata are sandy and pebbly. Then follow other coarse slates, grits, and flagstones, called by Mr. D. Sharpe 'Windermere rocks,' in which Lower Ludlow fossils occur, and a remarkable calcareous band, which is seen at Underbarrow, Docker Park, &c. This band, it is worthy of note, is charged with Starfishes similar to those which have been described as occurring in the Lower Ludlow rock of the Silurian region (p. 127). A very distinct representative of the Upper Ludlow succeeds, as proved both by position and fossils, but differs in being a siliceous flagstone much harder than its equivalent in Siluria—in short, akin to beds of this age in parts of

* See Quart. Journ. Geol. Soc. Lond. vol. i. p. 443.

South Wales. The series terminates upwards in strata which, on the banks of the Lune and near Kendal, are the counterparts of the uppermost zone in the Silurian region, and are charged with numerous fossils, some of the most striking of which are large Crustaceans (Ceratiocaris, Eurypterus, &c., see p. 140)*. As the district around Kendal is now undergoing the critical survey of that experienced Silurian geologist Mr. Aveline, we may be sure that these rocks of Cumberland will be placed in precise correlation with the types of Shropshire and North Wales, and their outlines accurately defined.

In this district, however, the ascending succession is interrupted†. Instead of the complete series of the Old Red Sandstone, which has been described in Shropshire and Herefordshire, and a conformable gradation and passage upwards into its overlying sandstones and marls, the Silurian rocks of different age are at once unconformably flanked and overlapped by red masses, chiefly coarse conglomerates, which alone represent the great and complex Devonian group of other tracts.

Isle of Man.—In correlation with their observations on the Lake country of Cumberland and Westmoreland, Messrs. Harkness and Nicholson have shown that the oldest rocks in the Isle of Man are of Lower Silurian age, and evidently of the same date as the Skiddaw slates, not only on account of their lithological character, but also from their containing the common Skiddaw fossil Palæochorda major‡.

Silurian Rocks of Scotland.—In the early days of Scottish geology, its illustrious founders, Hutton and Playfair, considered the schistose mountains in the South of Scotland to be void of all traces of life, until their able associate, Sir James Hall, detected a few fossil shells in a limestone at Wrae Hill, in Peebles-shire, which had been regarded as 'primary.' The merit of transferring these strata to what was then termed the 'transition class' of rocks, or those recognized as old fossiliferous deposits, is also in great measure due to the late Professor Jameson; for though he valued lightly organic remains, as was then usual with the scholars of Werner, he gave a clear general view of the rocks.

It was not until some years after the publication of the 'Silurian System' that the researches of Professor Nicol first indicated the relations of the Wrae fossils and the associated schistose masses to the known members of the series §; and since then other researches of that author, as well as

* The reader who desires to study the data by which our present knowledge of the geology of the Lake district has been acquired, must read the various memoirs of Professor Sedgwick in the Proceedings of the Geological Society, vol. ii. p. 675, and the Quart. Journ. Geol. Soc. vol. i. [illegible] vol. viii. pp. 35, 136; the Memoirs of Mr. D. Sharpe, Proc. Geol. Soc. vol. iv. pp. 23, 70; those by Professor Phillips, Geol. Trans. 2nd ser. vol. iii. p. 1, and vol. iv. p. 95; and Professor Harkness's important descriptions of the rocks and fossils of Cumberland and Westmoreland, in the Quart. Journ. Geol. Soc. vol. xix. p. 113, &c. (where, with Mr. Salter, he describes many Silurian fossils new to the country), and in vol. xx. p. 235 (where he gives an account of a hitherto unnoticed inlier of Silurian rocks around Dufton Pike).

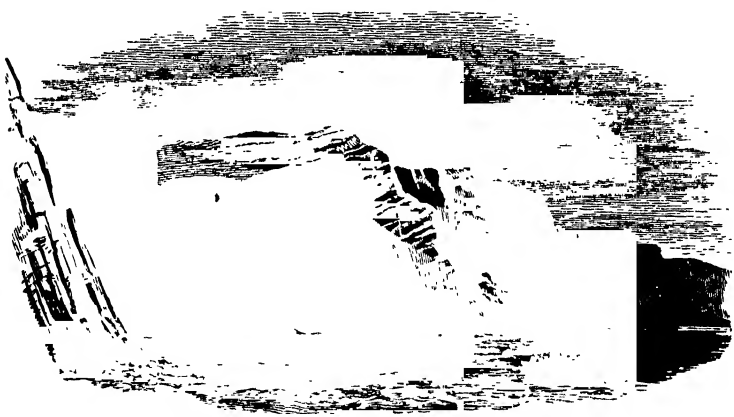
† Besides this general transgression and unconformity, it has been pointed out by Professor Sedgwick that the 'Old Red' contains many fragments of the Silurian Tilestones, which must have [illegible] (Quart. Journ. Geol. Soc. vol. i. p. 449).

‡ Quart. Journ. Geol. Soc. vol. xxii. p. 488.

§ For a complete historical sketch, see a notice by Mr. Hugh Miller ('Witness' newspaper, November 24th and 27th, 1852). A single fossil was found, but not described, by Laidlaw, the friend of Walter Scott; and Orthoceratites were afterwards discovered by Mr. Charles Maclaren in the Pentland Hills, and noticed in his excellent work 'The Geology of Fife and the Lothians,' 1839.

of Sedgwick, Moore, Cunningham, Stevenson, Harkness, the officers of the Geological Survey (particularly Mr. Geikie), and myself, have brought the Scottish masses into a distinct comparison with their true types.

Silurian rocks, and especially those of the lower part of the series, are now known to occupy a very large region in the South of Scotland. Ranging on the whole from E.N.E. to W.S.W., they appear in considerable masses in Berwickshire and Roxburghshire, and thence spread out in still larger areas over the counties of Selkirk, Peebles, Dumfries, Kirkcudbright, Galloway, Wigton, and Ayr. In short, they constitute, on the whole, the undulating moory hills which, from their prevalent wildness of aspect, have been called the South Highlands (or Southern Uplands). Subjected, as they have been, to numerous eruptions of granite, syenite, porphyry, greenstone, and other igneous rocks, some of these ancient schists have long been known to geologists for the remarkable curvatures they exhibit in the sea-cliffs of Berwickshire. A drawing is subjoined which represents such flexures and breaks, as seen in the cove called Petticoe Wick, near St. Abb's Head*.

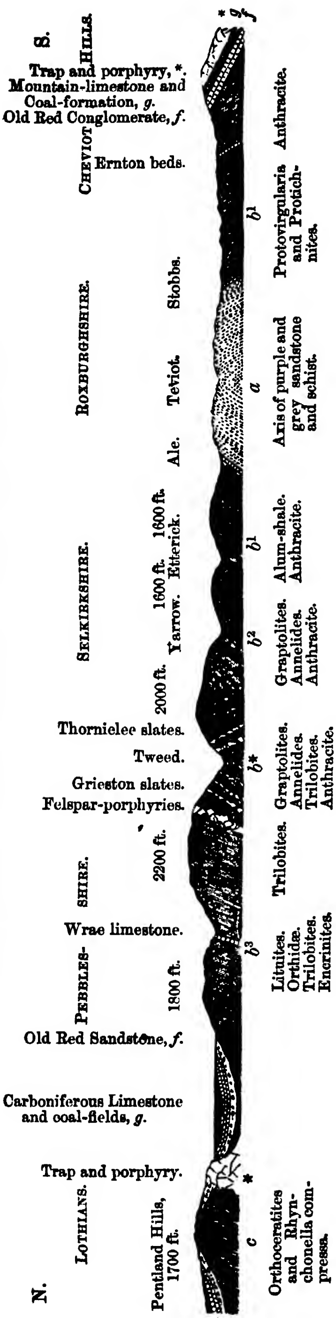


VIEW OF THE CLIFFS NEAR ST. ABB'S HEAD.
(From a Sketch by Sir A. Alison, Bart.)

As numerous similar contortions are visible also in the western prolongation of the same great series to the coast of Wigton and Ayr, we ought to be cautious in determining sections across the interior portions of a region where the surface of the round and undulating hills is obscured by moss, heath, and bog, and where exposures of the bare rock are rarely to be met with.

Difficult, however, as it has been to fix upon the oldest portion of these

* The woodcut is taken from one of several rapid, clever sketches made in my note-book, in the autumn of 1833, by Sir Archibald Alison, the historian, from a boat in which Sir John Hall of Dunglass and Professor Sedgwick were also my companions. This coast has since been mapped and described in detail by Mr. Geikie, 'Memoir on the Geology of Eastern Berwickshire' (Mem. Geol. Surv. 1864, p. 6 *et seq.*).



SILURIAN ROCKS OF THE SOUTH OF SCOTLAND. (Length of section fifty miles.)

inland masses of the Scottish greywackè, we have now reached that starting-point. When traversing the tract between Dumfries and Moffat, in 1850, it occurred to me that the dull reddish or purple sandstone and schist to the north of the former town would prove to be the true axis of the South of Scotland†; for this mass (similar to much of the hard rock of St. Abb's Head) evidently throws off anthracitic schists, with Graptolites, both to the south and to the north. Professor Harkness established this order, after my visit, by detailed sections in that parallel, ranging by the Dryfe Water‡. The same author has also communicated a memoir to the Geological Society, wherein he traces this axial line from the E.N.E. in Roxburghshire to the W.S.W. across Dumfriesshire, where, covered for a space by the red sandstone (Permian) of Corncockle and Dumfries, it seems to trend to the granitic mountain called the Criffel, in Kirkcudbrightshire §.

Professor Nicol, who first opened out the proofs, both physical and fossiliferous, that the South Scottish Hills are really Silurian, has satisfied himself that this true axis of the oldest and as yet unfossiliferous rock ranges by Teviotdale ‖. Proceeding from that centre, he prepared the annexed general section, which (minor flexures being omitted) exhibits a short ascending

† Quart. Journ. Geol. Soc. vol. vii. p. 162.
‡ *Ibid.* vol. vii. p. 52, and vol. viii. p. 393.
§ *Ibid.* vol. xii. p. 238.
‖ Meeting of British Association, Belfast, 1852.

section to the Cheviot Hills on the south, and a very long one to the Pentland Hills, near Edinburgh, on the north.

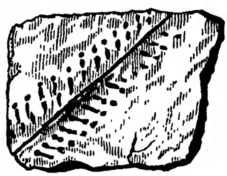
This traverse shows in the clearest manner an upward development from the lowest divisions of the series; so that, after placing other transverse sections in parallelism with it, whether along the east coast or from Dumfries and Moffat, we will then pass to the west coast, where we meet with higher and much more fossiliferous masses of the Silurian system.

Casting his eye over the foregoing diagram*, the reader will understand the comparison which is drawn between these Scottish strata and those of the typical region of Siluria and Wales, described in the second, third, and fourth Chapters.

Beginning with the rocks which form the axis of Roxburghshire and Dumfriesshire, it is seen that they are of purplish or dull red colours, and that, whether sandstones or alternating purple and grey schists, they are absolutely of the same composition as the bottom rocks of the Silurian region. Until a few years since, no fossils had been found near this Scottish basement rock; but in 1854 Sir W. Jardine detected Protovirgularia in purplish shale which, in the parish of Applegarth, lies immediately to the south of the axial line. At Binks in Roxburghshire, about three miles N.E. from Moss Paul Inn, and in the same range, Professor Harkness observed physical evidences of deposits formed in very shallow water, in the ripple-marks, cracks of desiccation, and fine alternations of sand and mud. On one of the grey-coloured layers of the latter he detected in 1855 the track of a Crustacean, a drawing of which is here given, it being the

FOSSILS (24). TRACK OF A CRUSTACEAN.

Protichnites Scoticus, Salter; from Binks, Roxburghshire. Half the natural size.



Impressions of the feet and of the sternal or the caudal portion of the body.

earliest sign of animal existence which we have obtained in Scotland. The creature which left these markings was possibly a shrimp-like Crustacean, as suggested by Professor Harkness, and analogous to the Hymenocaris (Salter) of the Lingula-flags, of which a sketch is given (p. 44). The curious impressions above figured are not at all unlike those far larger prints which Prof. Owen has so well described, and which were found by Sir W. E. Logan in the Potsdam Sandstone of Canada (Quart. Geol. Journ. vol. viii. p. 214). In this case, however, it would appear that a single pair of

* Reduced from a large coloured section exhibited at the Belfast Meeting of the British Association for the Advancement of Science, 1852. Since this section was made, the region at its north-western end has been the subject of a detailed survey by Mr. Geikie; and he has given a section conveying the true relations of the rocks in the Pentland Hills. (See Proceedings of Royal Society of Edinburgh, vol. v. p. 350.) This section shows how the Lower Silurian are succeeded by strata containing Wenlock and Ludlow fossils.

legs successively produced the imprints (not four or five or more, as in the Canadian tracks); and they are most likely to have been made by an animal swimming with difficulty in very shallow water, such as Prof. Harkness shows from physical evidence to have been the condition of the locality (Quart. Geol. Journ. vol. xii. p. 243). The reader will find in the fifteenth Chapter, which treats of the Continental rocks of Silurian age, that the lowest fossiliferous rocks of the Thüringerwald contain Protovirgularia associated with Nereites.

Although the axial dome, *a*, of purple rocks, for the most part arenaceous, throws off schists to the south as well as to the north, and though on both sides anthracite and traces of Graptolites have been found in the beds marked b^1, the Silurian rocks are soon lost in the former direction under the red sandstone (Permian) north of the Solway Frith, or the Old Red and Carboniferous formations or porphyries of the Cheviot Hills. To the north of the axis of the Teviot, a long ascending section is presented to the observer, though it must be presumed that there are many flexures which are not marked in the diagram. In this direction the schists and greywackè, b^1, which are in parts alum-slates (Etterick), may represent in time, as suggested by Professor Nicol, the schists of North Wales with Lingulæ, though as yet the Scotch strata have afforded no such fossils. These are surmounted by other schists, here and there containing thin laminæ of anthracite, b^2, which formerly gave rise to the notion of coal being subordinate to these rocks. It has been surmised that this anthracite resulted from the carbonization of Sea-weeds, or possibly of Graptolites and Annelides; but the discovery by Nicol of some imperfect reed-like Plants in the rock, with a minute vascular or tubular structure in the burnt residue of the anthracite, has led to the suggestion that some sort of grassy vegetation existed on the adjacent lands, or some Zostera-like plants in the sea, during this ancient period.

The anthracitic schists, b^2, contain a few Phyllopod Crustacea † and many so-called Annelide-markings; they form the base of a vast thickness of graptolite-schists, which, after a synclinal flexure in the Yarrow Hills, show another anticlinal in the valley of the Tweed, b^*. Whilst the Thornielee slates, with their Graptolites and Annelide-marks (Nereites, Crossopodia) &c., are inclined southward, the Grieston slates, on the north bank of the anticlinal, plunge to the north, and then for the first time in ascending order we find Trilobites in addition to the Graptolites and Annelides.

Associated with felspar-porphyries (the whole representing the trappean and graptolitic group of North and South Wales), these rocks rise into mountains 2200 feet above the sea; and from them the sources of the Clyde, as well as of the Tweed, take their rise. Thence, the northern dip being continued, the whole of the preceding masses are seen to be overlain

† See Quart. Journ. Geol. Soc. vol. viii. p. 391. A larger species than those referred to has since been found by Professor Harkness; and Mr. H. Woodward has recently described another genus of these Crustacea from the same shales (Quart. Journ. Geol. Soc. vol. xxii. p. 503).

by the Wrae limestone of Peebles-shire, b^3, which, from its organic remains (Trilobites and Shells), has been paralleled with the Llandeilo limestone*.

All the associated schists and other strata were therefore termed Silurian by Professor Nicol (1846), the more so as the fossiliferous limestone reposed on schists containing Graptolites. In pursuing this traverse northwards, other overlying schists and slaty rocks are seen to overlie the Llandeilo (?) limestone of Wrae, though these are soon lost under and covered over by the Old Red Sandstone, *f*, and the Carboniferous formation of the Lothians, *g*. Beneath those deposits, *f*, *g*, we know not what flexures may occur in the subjacent or older rocks of the great intervening trough; but on reaching the Pentland Hills, hard schistose strata are again met with, nearly parallel to those we have left, and, like them, inclined to the N.N.W. at high angles. Under these circumstances only, it would be difficult to assign to the constituent strata of the Pentland Hills any more definite place in the series than that of Upper Silurian. Previously to the year 1839, the late Mr. Charles Maclaren had found an Orthoceras in these strata, which most resembled a Wenlock species; in 1858 Mr. Geikie detected Rhynchonella compressa, also a Wenlock species; and from this evidence it was inferred in the last edition of this work that these Silurian rocks of the Pentland Hills were of Wenlock age. Since that time Mr. Geikie has shown that they contain representatives of the Ludlow rocks, as will be pointed out a little further on.

A second traverse of the chain, near the eastern coast, or towards the sea-board of the Lammermuir Hills, exposes the lower members of the series just described. There the Teviotdale anticlinal axis, *a*, is marked by the course of the Lower Tweed. The purple schist seen to the north of Berwick, the outlines of which have been sketched (p. 150), appears, therefore, to belong to the same bottom rocks of the series. Further northwards, higher beds, the equivalents of the Peebles-shire groups, occur; and in these, on the Dye near Byreclugh, Mr. Stevenson of Dunse † has found a Graptolite, an obscure Coral, and slates with Annelide-impressions. As these beds lie in the line of strike of the Grieston and Thornielee slates, they probably coincide with them in age. The predominating dip of the strata is to the north-west, showing a general ascending section, notwithstanding the numerous convolutions, which are beautifully seen on the coast, and have been already adverted to. This region has recently been mapped and discribed in detail by Mr. Geikie, during the progress of the Geological Survey in Scotland ‡. He notices the occurrence of Graptolithus priodon at Siccar Point, of Diplograpsus pristis in dark shales at the head

* Among the fossils of the Wrae limestone found by Professor Nicol are:—Illænus Bowmanni, Salter; Harpes parvulus, M'Coy; Asaphus tyrannus, Sil. Syst.?; a species of Phacops; Cheirurus; Orthoceras arcuoliratum, Hall; Orthis calligramma, Dalman; O. biforata, Schlotheim; Strophomena tenuistriata, Sil. Syst.; Salter, in Quart. Journ. Geol. Soc. Lond. vol. iv. p. 205, and Professor M'Coy in the 'Brit. Pal. Foss. Mus. Cambridge,' pp. 248, 374, &c.

† See Proc. Geol. Soc. Lond. vol. iv. pp. 29 and 79; and Quart. Journ. Geol. Soc. Lond. vol. vi. p. 418. I long ago examined the purple greywackè or bottom rock, near Dunse, in company with Mr. William Stevenson.

‡ See Geology of Eastern Berwickshire (Mem. Geol. Surv. 1864), chap. ii., and Geology of East Lothian (*ib.* 1866), chap. ii.

of Lauderdale, and of Annelide-tracks both at Siccar Point and at several parts of the valley of the Dye Water. His memoirs contain the most detailed account which has yet been given of any part of the Silurian region of the South of Scotland, and may be referred to as illustrating the contortions, foldings, metamorphism, and intrusive rocks of the Silurian series in this part of the kingdom.

A third traverse of the South-Scottish Hills, made along the line of the Caledonian Railroad *, exhibits the same general features, and many of the same details, as the preceding parallel sections. The Dumfries axis of the older and unfossiliferous greywackè, as before stated, throws off anthracitic and graptolitic schists southward to Lockerby, and to Moffat on the north. The details of these must be sought for in the memoirs of Professor Harkness, who has shown to what a great extent some of the schists are charged with Graptolites. Among them may be cited the wide-spread forms of the Llandeilo flags—Diplograpsus pristis, D. folium, D. teretiusculus, and Graptolithus sagittarius, all found in the older rocks of Sweden, also Graplithus lobiferus, a Bohemian fossil, with other species found in Lower Silurian strata elsewhere in the British Isles, or peculiar to these deposits. Twenty-five species have already been enumerated from this district alone †. (See Foss. 12. p. 61.)

All these rocks, anthracitic and aluminiferous, which are charged with Graptolites and Annelides, dip northwards from Moffat to Abington, and thus pass under other masses visible in this direction. The latter, which occupy the tracts of the Lead Hills and other lofty summits, are metalliferous schists, in parts much altered, and penetrated by felspar-porphyries with other igneous rocks. They were celebrated for yielding gold-ore in the reigns of the Fourth and the Fifth James of Scotland. Associated with, or rather overlying them, is a rude breccia, partly calcareous, which may possibly represent the Wrae limestone of the diagram at p. 150. But further northward other and still thicker strata of Silurian age are visible, which are overlain by the Old Red Sandstone and coal-fields of Lanarkshire. Though satisfactory in exhibiting a good ascending succession from the base of the sedimentary series, I consider this section less perfect, in carrying out the order to beds on or above the horizon of the Llandeilo limestone, than that which is figured above (p. 150).

The fourth, or west-coast traverse, from Luce Bay across Wigtonshire and part of Ayr, does not develope the order of the lowest masses, but adds much to our acquaintance with the more fossiliferous strata of the system, by exhibiting beds more copiously charged with fossils than any other Silurian rocks in Scotland ‡.

* Prof. Nicol and myself examined this section together in 1850. See Quart. Journ. Geol. Soc. vol. vii. p. 137.

† See Harkness, Quart. Journ. Geol. Soc. vol. vii. p. 48; and M'Coy, Palæozoic Fossils of the Cambridge Museum.

‡ Accompanied by Professor Nicol, I examined this tract in 1850. Our fossil-collector was the late Alexander M'Callum, of Girvan, who searched every locality with great assiduity. See details in my Memoir on the Silurian Rocks of the South of Scotland, Quart. Journ. Geol. Soc. vol. vii. p. 137.

So contorted and fractured are the strata of the southern part of the series, that it is indeed no easy matter to place them in their exact relative places—even after much labour bestowed on the coast-sections of his native county (Wigton) by my friend Mr. John Carrick Moore. The black glossy slates of Cairn Ryan, and certain red schists, might lead us, from analogy, and from their containing the same species of Graptolites, to suppose that they represented the older portion of the previous sections, which lie above the Longmynd or bottom rocks. On the other hand, they are associated with a coarse conglomerate containing pebbles of granite and porphyry, with here and there blocks two feet in diameter; and this conglomerate so much resembles a rock of the Ayrshire district about to be described, which clearly dips under certain fossiliferous schists (of Kennedy's Pass), that the pebble-beds of Wigton and Ayr may be eventually placed on the same parallel. Along the coast, however, from Correrie Burn to the Stincher River, they are separated by so much igneous rock that it becomes impossible, without long and continuous labour, to coordinate the disrupted masses.

With the northern portion of this section I am best acquainted, and to it I now call attention. From the mouth of the Stincher to Kennedy's Pass, south of Girvan, the eruptions of porphyry, greenstone, and syenite are indeed on a grand scale (Knockdolian, Bennan Head, &c.). Owing to these great extrusions from beneath, the Silurian strata, accompanied by much serpentine and many metamorphosed schists*, have there been thrown into at least three flexures within the distance of a few miles, on each of the axes of which, or on the Stincher, Assell, and Girvan Rivers, limestones of the Lower Silurian age are brought to the surface. These schists and limestones are overlain in the contiguous troughs by other rocks, one portion of which consisting of coarse conglomerates, and another of shelly sandstone, represent parts of the Caradoc rocks; whilst certain sandy and calcareous flagstones seem, by their fossils, to be equivalents of the Llandovery rocks, and to indicate a passage into the lower member of the Upper Silurian.

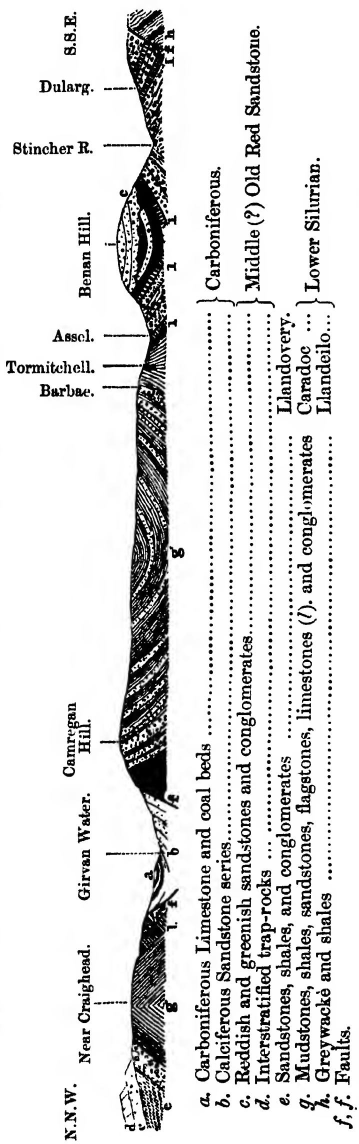
Referring for details to the memoir above cited, I will here very briefly describe some of the salient features of these Ayrshire deposits. The limestones on the Stincher and the Girvan Rivers contain the following fossils:—Orthis calligramma, O. confinis, Leptæna sericea, L. quinquecostata, Cheirurus gelasinosus, species of Illænus and Asaphus, Pleurorhynchus dipterus, and Corals of the genera Heliolites, Favosites, Omphyma, Strephodes, &c.

Most of the above species are Caradoc types; and with them is also found a species of the genus Maclurea of Hall, which is characteristic of the Chazy Limestone, one of the marked Lower Silurian deposits of North America.

* The igneous and metamorphic rocks of this tract have recently been described in considerable detail by Mr. James Geikie, of the Geological Survey, in the Quart. Journ. Geol. Soc. vol. xxii. p. 513. Some of the rocks which Mr. Geikie regards as metamorphic I still consider to be of igneous and eruptive origin, not only from their composition and structure, but from the part they play in disturbing the sedimentary strata.

Certain fine, micaceous, dark-grey, shelly sandstones, in the Mulloch Hill on the right bank, and in the Saugh Hill on the left bank of the Girvan Water, contain among other fossils the following species:—

Pentamerus oblongus; a variety of Atrypa hemisphærica; Orthis reversa; O. biforata; O. elegantula; Rhynchonella angustifrons; Strophomena pecten; Bellerophon dilatatus; Murchisonia cancellatula, a beautiful fossil; M. simplex, a Welsh species; Trochus Moorei; together with the well-known Silurian Corals Heliolites interstinctus and H. tubulatus, Petraia subduplicata, Favosites alveolaris, Ptilodictya (Stictopora, Hall) acuta, or Pt. costellata.



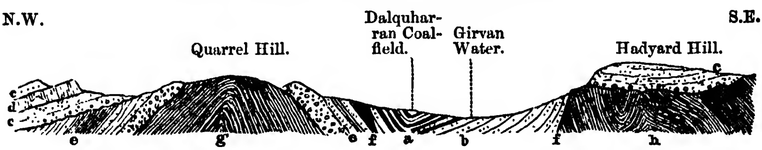
SECTION FROM NEAR CRAIGHEAD, ACROSS THE GIRVAN, ASSEL, AND STINCHER WATERS, TO DULARG NEAR BARR.

Most of these species occur in the Llandovery rocks, and particularly Pentamerus oblongus and Atrypa hemisphærica, which are the most abundant of the shells. There is also Rhynchonella (or Hemithyris) angustifrons of M'Coy, a species before mentioned (p. 88) as occurring in the Lower Llandovery rocks of Wales. Again, among the Trilobites, we have here Lichas laxatus, common in the limestone at Bala in North Wales, and, in the very same matrix, Calymene Blumenbachii. Now, although the last-mentioned Crustacean has been found throughout nearly the whole system elsewhere, it is by far more common in the Upper than in the Lower Silurian. Besides, it is here associated with Phacops Stokesi and Encrinurus punctatus, both of them fossils of the Llandovery rocks, and abundant in the Wenlock formation. The shales of Penwhapple Glen contain a large Orthoceras, which Professor M'Coy has designated O. politum, associated with Lower Silurian Grap-

tolites. Here, also, we have Orthoceras angulatum, Wahl., an Upper Silurian form. On the other hand, there is a large species not to be distinguished from O. vaginatum, Schloth., so common in the Lower Silurian of Scandinavia and Russia, and in addition O. bilineatum, Hall, a Lower Silurian fossil of America. The genus Cyrtoceras is also found here; and with these Cephalopods occurs a thin, finely striated Discina, the D. crassa of Hall, which is found also both in the Caradoc and the Llandeilo beds of Wales. There are, moreover, double and single Graptolites, both belonging to Lower Silurian species. So that in Scotland, as in England and Wales, and particularly as we ascend in the series, we meet with rocks in which the upper and lower types are mixed together. During the last three years the Geological Survey has been at work in Ayrshire; and Mr. Geikie, who has mapped the Girvan district here referred to, has furnished me with the annexed section (p. 156).

Another section, also prepared by Mr. Geikie, shows the detailed relations of the rocks in the tract north of Girvan and on both banks of the river.

SECTION ACROSS THE VALE OF GIRVAN AT DAILLY.



a. Carboniferous Limestone with coal-seams. *b.* Calciferous Sandstone series of the Carboniferous Formation. *c.* Reddish and greenish (Middle?) Old Red Sandstones and Conglomerates. *d.* Interstratified felspathic trap-rocks. *e.* Sandstones, shales, and conglomerates (Llandovery). *g.* Caradoc shales, mudstones, conglomerates, and limestone. *h.* Shales and greywackè: Caradoc or Llandeilo. *f, f.* Faults.

Although this is no place for lithological details, a few words must be said of a very striking conglomerate which lies low in the order of the strata. Among its rounded and waterworn pebbles, varying in size from musket-bullets to blocks of two and three feet in diameter, Professor Nicol and myself distinguished upwards of twenty varieties of rock. They consist of small specimens of earthy greywackè, and larger blocks of hard siliceous greywackè, lydian-stone, hornstone, felspar-porphyries of various colours, greenstone, syenite, and granite.

Such conglomerates, which may be indicative of the powerful and long-continued action of waves on a coast, are, however, only to be viewed as local phenomena, and may therefore be looked for in various parts of this ancient series in Scotland, just as they have been shown to occur at various levels in the Silurian rocks of England and Wales. They occasionally appear, indeed, in the coarse grits of the Longmynd or bottom rocks; and coarse conglomerates occur in the same unfossiliferous subjacent greywackè (Cambrian) of Carnarvonshire.

The shelly Silurian beds of Ayrshire being covered towards the north by

the Old Red and Carboniferous deposits, there is no evidence in that tract of a younger order of things beyond what may be viewed as a transition from the Lower to the Upper Silurian.

On the opposite side of the South-Scottish axis, however, the highly convoluted strata which form the southern headlands of Kirkcudbright Bay (Balmae Head and Little Ross), and the rocks on the east side of the Bay, are, judging from their fossil contents, of the age of the Wenlock shale. Hard and intractable as the Ireleth slates of Cumberland, which have been placed on the same parallel, and containing only very rarely nodules slightly calcareous, these argillaceous and siliceous schists have yielded a good many fossils. In them we find, it is true, the Lower Silurian forms, such as Orthoceras tenuicinctum (Chap. IX.) and Leptæna sericea; but from the same beds Mr. Salter has catalogued the following Upper Silurian types:—Phacops caudatus, Beyrichia tuberculata?, Orthoceras annulatum, Chonetes lata, Rhynchonella nucula, Pterinea lineatula, Grammysia cingulata. With these are associated other fossils, which pervade nearly the whole system, such as Atrypa reticularis, Halysites catenularius, Graptolithus priodon, and Bellerophon trilobatus. The last fossil, which in England occurs in the uppermost Ludlow rocks, is associated, in Ireland, with lower types.

In this way we have no means of defining, with greater precision, the age of the fossil-bearing promontories of Kirkcudbright than by saying that they overlie the great mass of the older Silurians, and contain a younger fauna. They appear, in short, to be more referable to the Wenlock than to the Ludlow formation. Through the discovery of the uppermost Silurian rocks in Lanarkshire (which are about to be mentioned), it might rationally be surmised that the time was when there existed also on the southern side of the Dumfries axis, a large and visible upward development of the youngest Silurian rocks, which ranged from the south of Scotland to meet the equivalents of the Wenlock and Ludlow rocks of the Cumbrian or Lake district of England—all which deposits are now concealed beneath the sea.

But on the immediate shore of the Bay of Kirkcudbright, all such links have been omitted; for there the lower part of the Upper Silurian series, as just described, is at once unconformably overlain by strata of the Carboniferous era*.

* The phenomenon of the unconformable superposition of the Carboniferous strata (with Mountain-limestone fossils &c.) to the Silurian rocks, along the coast of the parish of Kerrick, in Kirkcudbright, has been described in detail by Mr. Harkness, in a memoir read before the Geological Society, April 1853. This author explains by sections the extreme curvatures of all the rocks which he considers to be Upper Silurian, and parts of which he shows to have been shore-deposits. He further indicates the dykes of porphyry which protrude, and has endeavoured to mark the line of separation between the Lower and Upper Silurian, which on the whole rise up to the N.N.W., their upper beds being conglomerates and coarse sandstones. Professor Nicol and myself examined Balmae Head in 1851. Mr. Stevenson described the nodular shale of Little Ross Head, Ed. N. Phil. Journ. vol. xxxv. The organic remains above alluded to were collected by the Earl of Selkirk and Mr. Fleming. After describing the rocks of this small island, and showing that they contained Graptolites, both double and single, as well as Orthoceratites, &c., Mr. T. Stevenson, the eminent engineer, correctly inferred, sixteen years ago, that these strata were of Silurian age (Edinb. New Phil. Journ. July 1842).

Upper Silurian Rocks of Edinburghshire.—Reference has already been made to the Silurian rocks of the Pentland Hills. When the last edition of this work was published that portion of Midlothian was under examination by Mr. Geikie, in the course of the Geological Survey of Scotland. Since that time he has brought to light a large number of fossils which place the Upper Silurian character of the deposits beyond question. He has also furnished me with the following account of the locality:—

"During the progress of the Survey of the Pentland Hills I was fortunate enough to stumble upon a number of beds, among the Silurian rocks, charged with well-preserved fossils. An examination of these fossils by Mr. Salter showed that many of them were Ludlow species, and that a representative of the Ludlow rock had now been detected in a new locality. The strata are well seen both on the North Esk and the Lyne Waters, as well as in several smaller burns. Taking the section in the Esk, the following series in descending order may be traced:—

"Overlying unconformable conglomerate, greywackè, and trappean rocks, belonging to a middle part of the Old Red Sandstone. Red Sandstones, shales, and conglomerates, marking perhaps the base of the Lower Old Red Sandstone, passing down into:—1. Olive and brown sandy shales and mudstones, often full of well-preserved fossils. Thickness perhaps about 1000 feet. 2. Hard sandstone and quartzose grit, with Orthonota amygdalina &c. 3. Olive and brown sandstones and shales, passing down into green, grey, and reddish shales, with hard sandstone and greywackè bands; Dictyocaris sometimes abundant. Visible thickness about 2500 feet, when the beds are unconformably overlain by the first-mentioned conglomerates. The following are some of the fossils of the upper beds:—

"Chondrites verisimilis (a true Sea-weed), Amphispongia oblonga, Stenopora fibrosa, Favosites alveolaris, Protaster Sedgwickii, Encrinurus, sp., Phacops Stokesii, Pterygotus acuminatus, Entomis, Ceriopora granulosa, Atrypa reticularis, Orthis elegantula, Strophomena applanata, S. depressa, Leptæna transversalis, Orthonota amygdalina, Euomphalus funatus, Orthoceras Maclareni, O. subundulatum, Conularia Sowerbyi.

"These and other fossils are given in the Appendix to the Memoir on the Geology of the Neighbourhood of Edinburgh (Mem. Geol. Survey, 1861, p. 132). Since that memoir was published the list has been considerably increased, by Mr. G. C. Haswell and other members of the Edinburgh Geological Society*. While the upper part of the Pentland section may be regarded as of Ludlow age, it is evident that there is room for a representation of the Wenlock series also. This is rendered probable by the number of Wenlock species which have been obtained from these rocks."

The Orthoceras here figured (p. 160) was detected by my distinguished friend the late Mr. Charles Maclaren, and has been named O. Maclareni. It formed part of the collection of the eminent geologist Hugh Miller, who lent it to me for publication.

* See a Memoir by Mr. Haswell on the Pentland Hills, 1865.

FOSSILS (25).

Orthoceras Maclareni. Found in the Upper Silurian strata of the Pentland Hills.

Lanarkshire.—Unacquainted with any of the intermediate strata which may be found when these Upper Silurian rocks shall be traced from Edinburghshire on the E.N.E. to Lanarkshire on the W.S.W., I satisfied myself that in the latter county, to the west of Lesmahago, there is an ascending passage upwards from clay-slates with calcareous nodules and a rare Orthoceras, into black schists with large Crustaceans, which manifestly stand in the place of the uppermost course of the Ludlow rocks of Shropshire. This important fact was discovered by Mr. Robert Slimon of Lesmahago.

The relations of these dark-grey schists to the inferior rocks, as well as to the overlying Old Red Sandstone, are seen on the banks of the Nethan River and other tributaries of the Clyde, particularly the Logan Water.

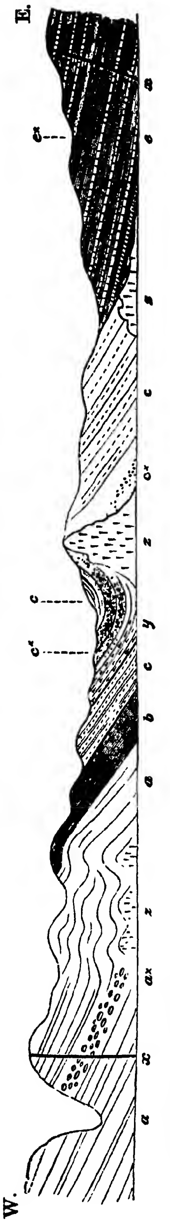
The accompanying diagram (p. 161) will fully explain the relations of these Upper Silurian rocks to the overlying masses of Old Red Sandstone and Carboniferous rocks. It was in the beds *a* that Mr. Slimon detected the remarkable Crustaceans which I then acquired from him, and which, being deposited in the Museum of Practical Geology, were first partially described by Professor Huxley and Mr. Salter in the Journal of the Geological Society, as a sequel to the memoir wherein the geological relations of the tract were explained by myself*.

Rising out from beneath the Lower Old Red, upon the Logan Water banks, these dark-grey beds occupy precisely the same horizon as that uppermost zone of the Silurian rocks of Shropshire and Herefordshire which includes the Bone-bed and the Downton Castle building-stone, and to which, where it graduates up into the Old Red, the names of 'tilestones' and 'passage-beds' have been given, as before explained. We have even the characteristic shells of the zone—Platychisma helicites and Lingula cornea.

The large Crustaceans which chiefly characterize the dark clay-slate, *b*, belong to those Pterygoti which occur, as we have seen, at intervals throughout the Upper Silurian rocks and are strikingly prevalent in their uppermost beds. In the woodcut at p. 162 are represented the principal species discovered in Lanarkshire. They appear to be specifically distinct

* Professor Ramsay and myself visited the localities near Lesmahago accompanied by Mr. Robert Slimon; and afterwards preparing the accompanying section, I published it in a short memoir descriptive of the general relations of the deposits in this tract (Quart. Journ. Geol. Soc. vol. xii. p. 17). Since that memoir was printed, Mr. Geikie has published a more detailed account of the structure of the Upper Silurian rocks and Lower Old Red Sandstone of the Lesmahago tract (Quart. Journ. Geol. Soc. vol. xvi. p. 312).

DIAGRAM EXHIBITING THE GENERAL RELATIONS OF THE UPPER SILURIAN ROCKS TO THE OVERLYING PALÆOZOIC STRATA IN THE PARISH OF LESMAHAGO. (From the Quart. Journ. Geol. Soc. vol. xii. p. 17.)



e^*. 'Black band' ironstone ....
e. Shales, sandstones, Productus-limestones, limestones, and coal... } Lower Carboniferous rocks.
c, c^*. Old Red Sandstone and Conglomerate............ } Lower Old Red Sandstone.
a, b. Dark-coloured schists with Pterygotus............
a^*. Calcareous nodules in clay-slate .... } Upper Silurian rocks.
a. Clay-slates ....

x, x. Trap-rocks.
y. Bedded porphyries.
z, z. Eruptive porphyries.

from any of the forms known on the same horizon in England.

The near alliance of these large Crustacea to some of the minuter recent forms has been fully explained by Professor Huxley in the memoir above mentioned, and will be touched upon in the Chapter on Organic Remains. The number of species must have been very great, more than twenty being known in Britain.

With them are associated, not only in Lanarkshire, but in Shropshire and Westmoreland, other, very curious, shrimp-like animals, apparently allied to the Phyllopodous Crustacea of the present day *. They have been called Ceratiocaris by Prof. M'Coy; and the fine specimens collected in the South of Scotland and other localities have clearly shown that to this genus must also be referred those singular spine-like prongs which the same author described under the name of Leptocheles. A figure of the genus, as restored, was given in the Quart. Journ. Geol. Soc. for 1856, vol. xii. p. 33; and the fossil will be figured in Chapter X.†

The reader who refers back to the figure of Hymenocaris vermicauda of the Lingula-flags (p. 44), will see that animals of the same general form were in existence in the earliest time of the Silurian epoch.

Fragments of large Crustaceans of the group of Eurypterida ‡ (Burmeister), to which the Pterygotus belongs, have also been found in the 'Tilestones' of Westmoreland; and

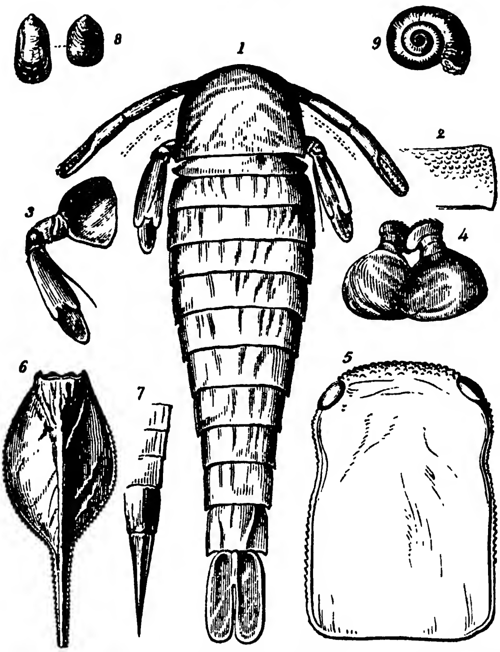
* Such as Apus and Nebalia.

† See Pal. Foss. Woodw. Mus. Pl. I. E. fig. 7; Quart. Journ. Geol. Soc. vol. ix. p. 13; and *infrà*, p. 236, for a proof of Prof. M'Coy's acumen in distinguishing some of these Crustaceans from the defences of Fish.

‡ See Palæoz. Fossils, Woodwardian Museum, Fasc. 1.

in these localities they are accompanied, as in Scotland, and at Ludlow, Kington, &c., by the small Lingula cornea.

Fossils (26). Crustacea and Shells of the uppermost Ludlow Rocks, Lanarkshire.



1. Pterygotus bilobus, Salter; half the natural size. 2. Portion of a body-joint, to show the peculiar sculpture. 3. Swimming-foot, natural size, but with the large basal joint incomplete. Fig. 4 shows a pair of these great foliaceous joints, with their inner serrate edges (the true mandibles are only indicated by their palpi in dotted lines, fig. 1). [In this restoration the body is rather too narrow, and has one segment too few.] 5. Head (reduced to one-half) of Slimonia acuminata, Salter. 6. Tail of the same (reduced to one-fourth). 7. Tail and a few body-joints of Eurypterus lanceolatus. 8. Lingula cornea, Sow. 9. Platychisma helicites *, Sow.

In Southern Russia (Podolia) similar large Crustaceans, analogous to Pterygoti, were found in strata lying beneath rocks which are known to be of Devonian age; and to one of these Dr. Fischer gave the name of Eurypterus tetragonophthalmus. M. d'Eichwald † has detected several species, one of which he figures as Eurypterus remipes ‡, Dekay, in the Isle of Œsel in the Baltic,—*i. e.* in a limestone which my colleagues and myself referred to the highest Silurian stage, and which Professor Schmidt of Dörpat has shown, by many of its fossils, to be an exact equivalent of the Upper Ludlow rock §. In the North, therefore, as in the South of Russia

* Formerly regarded as a Trochus.

† Bull. Soc. Imp. Nat. Moscou, 1854, vol. xxvii. p. 100.

‡ Prof. J. Hall, of Albany, refers this specimen figured by d'Eichwald to E. tetragonophthalmus.

§ Murchison in Journ. Quart. Geol. Soc. vol. xiii.

the zone under consideration, when clearly exposed, is everywhere characterized by large and peculiar Crustacea, no one of which has ever been found in the Lower Silurian rocks.

In North America it has been long known, from the writings of Dekay, Harlan, and Hall, that both Eurypteri and Pterygoti occur in a black, so-called greywackè slate at Westmoreland in Oneida County, New York, which will probably be found to be on the parallel of the Upper Ludlow rock. And even in Canada, as we learn from the collections of Sir W. E. Logan, species of Eurypterus or Pterygotus occur. The discovery of the large Eurypterida in the same geological zone in other distant regions is therefore peculiarly satisfactory.

Wherever these large Crustaceans are found, and with them small Lingulæ and Spiral Shells, we may be sure that we are at or near the very summit of all rocks to which the term Silurian can be applied, and that the next overlying stratum belongs to the first great era of Fishes, the Devonian or Old Red Sandstone.

Altered (Metamorphosed) Lower Silurian Rocks, and their Superposition to Cambrian and Laurentian Rocks, in the North-western Highlands.—In the preceding brief sketch of the older strata of the south of Scotland, I have made few allusions to the igneous rocks which have been intruded among the Silurian deposits. In numberless cases, however, whether around the granite of Criffel and Cairnsmuir, or the porphyry of Tongueland immediately to the north of Kirkcudbright, the schists which are in contact with such eruptive masses are so highly metamorphosed, that no one who looks at the effects can doubt as to their cause.

The view of much more extended metamorphism in the North of Scotland (due to a much grander cause) was indeed suggested by me in 1851 *. I then endeavoured to show that certain bands of clay-slate, and of chloritic and micaceous schist, forming the southern zone of the Highlands, with their interstratified limestones, were probably nothing more than metamorphosed Lower Silurian rocks, similar in age to the unaltered strata of the South of Scotland, and which, ranging parallel to them, come out to the surface again in broad undulations, associated with many granitic and other eruptive rocks, to the north of the great central Caledonian trough of Old Red Sandstone and overlying coal-fields †.

One of these great undulations, which occur in the rugged mountains of the west, called Argyll's Bowling-Green, exhibits an axis of mica-schist throwing off to the north and south great thicknesses of chloritic schist and altered sandstone, with included and regularly stratified limestones, all trending from W.S.W. to E.N.E., parallel to the Silurian rocks of the South of Scotland.

In a subsequent memoir, Professor Nicol supported this idea, which he had long entertained, by striking facts and good reasoning. Describing

* See Quart. Journ. Geol. Soc. vol. vii. p. 168. † Ibid. p. 160.

the geological structure of Cantyre, and stating that the so-called mica-slate of that tract is only a partially altered micaceous sandstone, which seems almost to pass upwards into the Old Red Sandstone, he shows how all the other crystalline strata conform to and bend round the granitic nucleus of Goatfell in Arran. In confirmation of the probable identity of some of the crystalline strata of the north with the Silurian rocks of the south, he mentions the illustrative fact that calcareous matter prevails most extensively towards the western extremity of both groups of rocks. In the South-Scottish Silurian strata no calcareous beds are known at their eastern termination; limestone only begins to appear in feeble courses in Peebles-shire, near the centre of the chain, and becomes very abundant (as above described) in Ayrshire. It is the same with the crystalline strata of the north. In the coast-section from Stonehaven to Aberdeen, no calcareous bands occur; in Forfarshire and Perthshire several are known; they become still more abundant in the north of Argyleshire; and in Cantyre (as in Ayr) we have a great group of limestone rocks.

These views of the metamorphosis of the Lower Palæozoic deposits into those stratified crystalline rocks which occupy so large a portion of the Highlands of Scotland have, since the publication of the first edition of this work, been reduced to a certainty as respects the north-western part of Sutherlandshire, by a discovery made by Mr. C. Peach. That keen-eyed collector, though residing far off at Wick, had, in a rapid excursion to Durness, detected there certain fossil shells in the crystalline limestone, which in that region is subordinate to quartz-rock. Now, according to Sedgwick, myself, and other geologists, including M'Culloch *, these quartz-rocks and limestones, associated with and passing under micaceous and gneissose schists, and resting upon ancient gneiss, are overlain on the east coast by the whole series of the Old Red Sandstone, which is made up of the materials of such preexisting crystalline rocks: these will be treated of hereafter.

Judging, then, from their relative geological position, of which, after an interval of twenty-eight years, I reassured myself by a visit during the summer of 1855, I had little hesitation in suggesting that these rocks were of Lower Silurian age†. In them my companion Professor Nicol and myself detected an Orthoceratite, but too imperfect to be referred to any known species. The Whorled Shell first discovered by Mr. Peach, many polished sections of which were examined, threw indeed a little more light upon the subject; and specimens which the same zealous and unrivalled collector subsequently detected in these rocks, having been examined and described by Mr. Salter, established the correctness of my view.

The large Whorled Shell, one of which is here drawn, has proved beyond

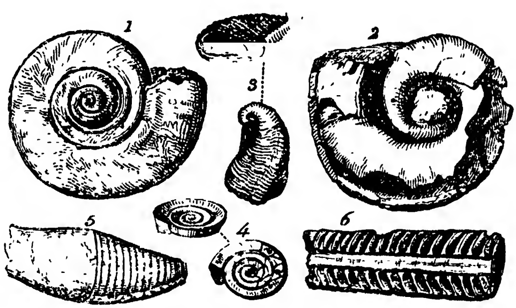
* See Sedgwick and Murchison, Trans. Geol. Soc. n. s. vol. iii. p. 125.
† See Report of British Association, 1855, Glasgow, Trans. of Sections, p. 85.

a doubt to be a true Lower-Silurian Maclurea. The upper surface of the shell is shown in Foss. 27. f. 1, and its lower surface in f. 2. The species differs from M. magna (Hall) of North America in the slight convexity of the whorls beneath, and from M. Logani (Salter) of Ayrshire, Foss. 40. f. 1, by the greater number of turns of the spire. The operculum, Foss. 27. f. 3, is of a most peculiar form, as may be seen by comparing it with that of M. Logani, Foss. 40. f. 1*a*. It is almost spiral; and this greatly helps to strengthen the opinion of the late Dr. S. P. Woodward*, that the genus may be one of the most ancient forms of the Rudista, a group not previously known to occur below the horizon of the Oolitic formations. See also page 198.

With this Maclurea, so decided in its bearing upon the age of the rocks in which it is imbedded, are associated other forms no less confirmatory of the identity of this group with the Lower-Silurian rocks of North America. They are here grouped in the same woodcut, in order to explain at a glance the general fossil contents of these Highland rocks.

Ophileta compacta, Foss. 27. f. 4, the smooth Orthoceras with large compressed siphuncle, f. 6, others with an annulated surface, and a species of Oncoceras, f. 5, all closely resemble fossils of the Lower-Silurian rocks of North America, which range from the Calciferous Sand-rock up to the

FOSSILS (27). LOWER SILURIAN SHELLS FROM THE NORTH-WESTERN HIGHLANDS.



1. Maclurea Peachii, Salter, upper side. 2. The same, lower surface. 3. The long, twisted operculum; two views. 4. Ophileta compacta, Salter. 5. Oncoceras, sp. 6. Orthoceras, with compressed siphuncle, like a Canadian species.

Trenton Limestone, both inclusive. Thus, for example, although the Oncoceras, f. 5, is specifically distinct from any published American species†, yet, when taken with the forms above enumerated, and particularly with Ophileta compacta, which is identical with a Canadian species, there can be no doubt that these Highland strata occupy the horizon assigned to them. It is also to be observed that these Scottish and American rocks resemble each other, to a great extent, in mineral composition as well as in their fossil contents.

The lower quartz-rock of this group in Sutherland is characterized by

* Manual of the Mollusca, p. 202.

† See Hall, Pal. New York, vol. i. pl. 41.

abundant traces of Annelides—both the large Scolithus linearis (Quart. Journ. Geol. Soc. vol. xv. p. 368) and the minute shelly Annelide which is here figured.

FOSSILS (28). ANNELIDE-TUBES FROM THE NORTH-WESTERN HIGHLANDS OF SCOTLAND.

Small, thick, shelly tubes of Annelides (Salterella Maccullochii, Salter).

Collected from the Lower Quartz-rock of Durness, Sutherland, by Mr. C. Peach.

Although the tube of this Salterella (Billings) is thicker in proportion than in any known Serpulites, it was provisionally referred in my last edition to that genus, and named, at my request, Serpulites Maccullochii by Mr. Salter, after the distinguished geologist who first noticed it *.

These fossil-bearing beds of Sutherland are clearly and conformably covered by other crystalline rocks, whether consisting of quartzose mica-schists and flagstones or younger strata having the characters of gneiss. One of the chief objects of my last visit to the Lower-Silurian limestones of Durness and Assynt † was to be satisfied, by another appeal to nature, that there were quartz-rocks above as well as below the fossiliferous limestone. Such a succession, followed symmetrically upwards by mica-schists, flagstones, and a younger gneiss, was again seen on the eastern side of Loch Eribol, where that physical order was observed thirty-one years ago by Sedgwick and myself. In 1859, in company with Professor Ramsay, I traced the same relations from Loch Eribol on the N.N.E., along intervening spots to the east end of Loch Stack and the western end of Loch More, and again in tracts lying on and to the east and south-east of Loch Assynt,—a distance along the strike of not less than forty miles from N.N.E. to S.S.W. Another proof of the soundness of this general view is seen in the fact that when the older or fundamental gneiss reappears amidst the overlying strata, as between Loch Durness and Loch Eribol, it throws off quartz-rocks and limestones to the N.W., and places them in a basin,—a fact observed by Mr. Peach, but which escaped the notice of former observers. Now, if the fundamental gneiss had been thus protruded to the surface in other and more eastern places, similar reversals of the dip might have been looked for; but no such basin-shaped arrangements are seen to the east of the tracts where the order of succession has been described; and

* Speaking of these obscure little fossils, in a Lecture on the Geology and Scenery of the North of Scotland (1866), Professor J. Nicol says (p. 31), "In the quartzite period organic life undoubtedly existed. Twoscore years ago Dr. Macculloch pointed out curious conical hollows, ending in long pipe-like bodies. These he described as Worm-holes, the prototypes of those seen on the shore, where the Lobworm sinks into the sand left dry by the retiring tide (Geol. Trans. vol. ii. p. 461). We have seen other, smaller holes identical in form with the holes which some small Crustacea on the Kyle of Durness are now digging in the sand washed out of these very rocks. The same sand is now lying in the same place, and beings of like organization are still burrowing it out for food or shelter. Yet the mind almost refuses to grasp the myriad ages that have intervened. The poor worm or insect in its daily occupation was building itself a monument 'ære perennius'—a tomb more enduring than king or kaiser. The moral needs not be drawn."

† Orthoceratites have been detected by Mr. Peach and myself in Assynt.

hence it follows that the older gneiss cannot be supposed to be reproduced as a surface-rock in the lofty mountains of the Central Highlands without calling in faults and inversions of stupendous dimensions. Wherever faults exist, it has been shown by Mr. Geikie and myself (Quart. Journ. Geol. Soc. vol. xvii. p. 193) that the order of superposition which I have indicated is always maintained. Again, if the Laurentian gneiss had been brought anew to the surface in the Central Highlands or on the east coast, we should expect to find it with the same characters and direction as in the west, and equally surmounted by Cambrian conglomerates and Lower Silurian quartz-rocks and limestones. But this is never the case; and the truth is, that all the rocks we see on the west coast are deeply buried, as we advance to the east and south, under flag-like micaceous strata, which are very dissimilar to the old Laurentian gneiss.

The granitic veins of the north-west coast are, indeed, essentially different from the massive granites of the east. The former are subordinate to a rock which underlies the oldest conglomerate and sandstone of the British Isles, whilst those of the south-east penetrate and alter strata that are evidently nothing but mica-schists and quartzose flagstones, which, though essentially different from the old gneiss at certain distances from such granitic intrusions, have necessarily some resemblance to them at such points of alteration and contact. Yet, that these mica-schists and flaggy beds of the east really overlie all the inferior masses of older gneiss, Cambrian sandstones, and Lower Silurian quartzites and limestones, no one can doubt who proceeds from Assynt, by Strath Oikel and Lairg, to Bonar Bridge. He will there see that all the Lower Silurian rocks of the north-west and west are covered by a flag-like micaceous series of very different and uniform structure, the strata of which dip steadily to the E.S.E., particularly on the banks of the Oikel, until they are broken through by the younger granitic masses in question, and are at such points necessarily both altered and much dislocated.

Again, if some one should suggest that the quartz-rock of the Scarabin Hills of the south-eastern part of Caithness may represent the old lower quartz-rocks of the west coast, I would beg him to examine the structure and relations of the two, and he will abandon that idea. The quartzites of the west are manifestly altered sandstones which, whether they lie upon purple Cambrian conglomerate and sandstone or on the ancient gneiss, are quite distinct from the pure quartz-rock of the Scarabins, which is simply a mass of the grey overlying quartzose rocks void of limestones, and metamorphosed by the powerful eruptions of granite which, enveloping all such stratified rocks on the banks of the Langwell and Berridale Rivers, jut out on the coast in the bold promontory of the Ord of Caithness, where the passage of the granite into compact felspar-rock may be admirably studied.

However, therefore, certain details may hereafter be settled, this great

feature of the reform in the classification of the older rocks of the North of Scotland stands out among the most prominent geological advances which of late years have been made in Britain; and I rejoice that the hypothetical views I had for some time entertained were borne out by a rigorous appeal to nature, as now attested by my associates Professors Ramsay and Harkness and Mr. Geikie.

As the age of the limestones and quartz-rocks of the North Highlands, with their associated mica-schists &c., has been a *quæstio vexata*—the lamented Hugh Miller having hypothetically suggested that they might be the representatives of the Old Red Sandstone and Caithness flags of the east coast, and Professor Nicol having at one time considered them to be metamorphosed Carboniferous rocks* (neither of which views can be sustained)—it is satisfactory to me to find that the old view of Professor Sedgwick and myself, with respect to their relative physical position, has been supported by other observers and the independent evidence of fossils.

This discovery of North-American Lower Silurian fossils in the northern extremity of Scotland is also of deep importance in general geological reasoning; for it will be hereafter shown that many of the same species of organic remains in rocks of this age extend throughout certain latitudes, over areas very remote from each other—or, in other words, that the Scandinavian, British, and North-American† Silurian rocks have the same typical characters.

When the first edition of this work was published, I entertained the belief, in common with my early associate Sedgwick and our precursor M'Culloch, that the striking mountain-masses of red conglomerate and hard grit on the north-western coast of the Highlands‡, which rest in layers more or less horizontal on low and gnarled bosses of highly inclined and ancient granitoid gneiss, as represented in the vignette at p. 170, were really a part of the Old Red Sandstone of Scotland§. Re-examination, however, of those tracts‖, compelled me to abandon that view. I then saw that these conglomerates, resting on the oldest or granitoid gneiss of the Highlands, as around Loch Assynt, were really inferior to those quartz-rocks and limestones in the prolongation of which to the north coast of

* Quart. Journ. Geol. Soc. vol. xiii. p. 36.

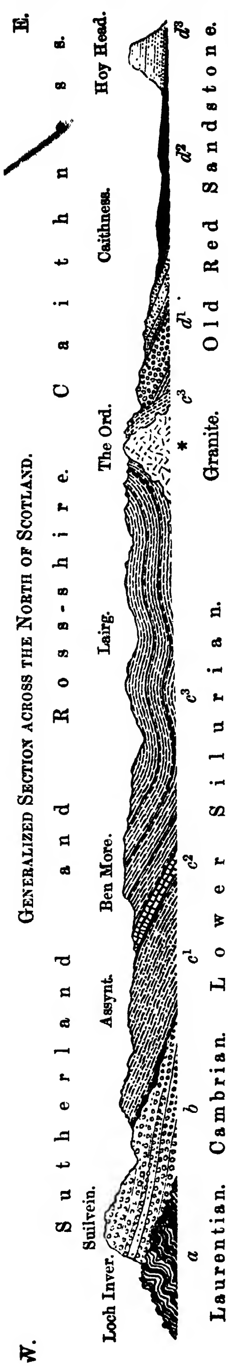
† The great Maclurea of the Lower Silurian rocks of Ayrshire has been identified by Professor M'Coy with the M. magna, Hall; and in Ireland, one of the Lower Silurian Trilobites is an American species, the Isotelus gigas, Dekay.

‡ My first visit to the west coast of the Highlands was made in 1826, accompanied by Lady Murchison, during which my attention was almost exclusively devoted to descriptions of the Oolitic and Liassic strata of the E. and W. of the Highlands (see Trans. Geol. Soc. 2nd ser. vol. ii. p. 293 &c). In the following year Professor Sedgwick and myself made that survey which enabled us to write the memoir upon the Old Red Sandstone of Scotland, which is printed in the Geological Transactions (n. s., vol. iii p. 153). Although we encountered bad weather in Assynt, which prevented us from making accurate distinctions among the rocks of that tract, we even then noted a conglomerate and grit as underlying to some extent the quartz-rocks and limestones of Sutherland. At that time no one had begun to classify any fossiliferous strata below the Old Red Sandstone, and all the old Scottish conglomerates, which are now being referred to Cambrian, Silurian, or Devonian ages respectively, were then grouped with the Old Red Sandstone. Having been prevented from detecting the unconformity on the west coast which has since been noticed, we naturally concluded, with M'Culloch and others, that the conglomerate of the west coast was of the same age as that on the east,—an error which will be specially dwelt upon in the 11th Chapter, when treating of the Old Red Sandstone.

§ See M'Culloch's Western Islands of Scotland; Cunningham's Mem. Highland Society, vol. xiii. p. 73; Nicol, Journ. Geol. Soc. vol. xiii. p. 17.

‖ Accompanied by Professor J. Nicol, in 1855.

GENERALIZED SECTION ACROSS THE NORTH OF SCOTLAND.



This section is given upon established data, and, following a line curvilinear in Caithness, it expresses at one view the order of the older rock-formations in the North of Scotland. Looking northward, the reader has on his left, upon the western coast, the Laurentian gneiss, *a*, and the overlying conglomerate of Cambrian or Longmynd age, *b*, the eroded edges of which are surmounted by the lower quartz-rock, c^1, the fossiliferous limestone, c^2, and the upper quartzose, micaceous, and gneissose rocks, c^3, all of Lower Silurian age. One only of the intruding bosses of granite, *, is introduced, near the junction of the quartz-rocks and the Old Red series. Lastly, the Old Red Sandstone is seen overlying these rocks, and consisting of great lower conglomerates and sandstone, d^1, Caithness flags and schists, d^2, and Upper Old Red, d^3. The last three deposits are equivalents of the Devonian group, and will be described in a subsequent Chapter.

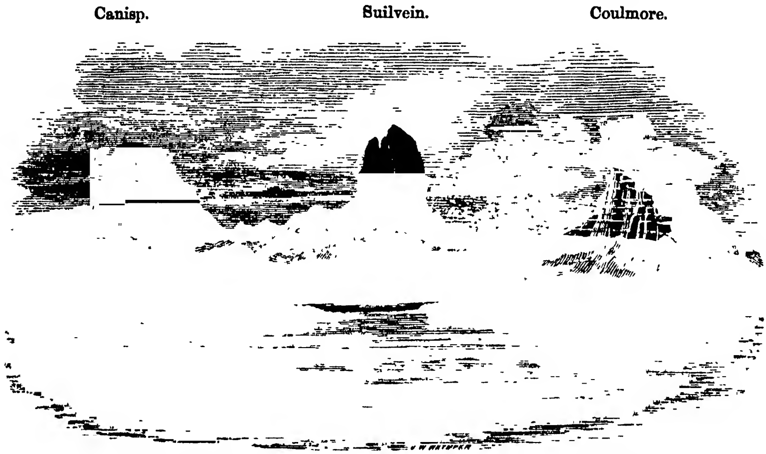
Sutherland Mr. C. Peach detected those fossils which enabled me to suggest that they belonged to the older Silurian rocks (p. 164). (See the coloured Frontispiece to the volume.)

The age of the fossiliferous rocks being thus definitely settled, it followed that the subjacent red sandstone, grit, and conglomerate must form either the base of such Lower Silurian, or belong to the remoter Cambrian era. Now, from observations which I made in 1858, it became certain that the first of these views could not be entertained; for it was clearly demonstrated that the lowest beds of the Silurian quartz-rock series overlap transgressively or unconformably the edges of the subjacent sandstone and conglomerate†. By this phenomenon we are taught that an interval elapsed between the completion of the pebbly and gritty beds that constitute the upper masses

† Although Professor Nicol and myself saw clearly, in the summer of 1855, the *infraposition* of a red conglomerate and sandstone to the quartz-rocks and limestones of Assynt (as observed also by Hugh Miller), we were prevented by storms from sufficiently extending our observations to ascertain if there was any break between these two deposits. Being aware that my friend Colonel James, R.E., the Superintendent of the Ordnance Survey, was about to explore these tracts on a tour of duty in the following summer, and knowing his talent as a field-geologist, I requested him to look to the relations of the beds; and I have much pleasure in stating that I was first made acquainted by him with the fact of the unconformability of the younger to the older formation along the flank of Suilvein (July 1856). Later in that summer, Professor Nicol observed the same phenomenon on a larger scale, and ascertained that it extended over a larger area of the western shores of the Highlands. See his memoir 'On the Red Sandstone and Conglomerate and the superposed Quartz-rock, Limestone, and Gneiss of the N.W. coast of Scotland,' Quart. Journ. Geol. Soc. Lond. vol. xiii. p. 17 &c., with clear and accurate sections. It is right to remark that part of the overlying group here spoken of as gneiss is merely one of the Lower Silurian rocks more altered than the other strata of quartz, marble, &c., and is of a very different character from the immeasurably older granitoid Laurentian gneiss, which is represented in the accompanying sketch and section as forming the buttresses on which the red sandstones and conglomerates of Cambrian age are seen to repose.

of the mountains represented in the following vignette, and the commencement of the deposit of those sandy and calcareous beds, since converted into quartz and marble layers, in which the Lower Silurian fossils were entombed (c^1 & c^2 of the section, p. 169).

It followed, therefore, that the subjacent red sandstone and conglomerate, *b*, reposing upon the most ancient gneiss of Britain, are to be considered of the same date as the similarly constituted purplish-red and pebbly sandstones of the Longmynd, which, in the typical region of Shropshire, underlie all the Silurian strata (p. 24). There, however, as well as around Harlech in North Wales, these Cambrian rocks graduate upwards into the superjacent Silurian rocks; and the period occupied in



MOUNTAINS ON THE WEST COAST OF SUTHERLAND AND ROSS.

The above pictorial view, from a sketch in my possession taken by that accomplished Highland chieftainess the late Duchess Countess of Sutherland, represents the three isolated mountains of Canisp, Suilvein, and Coulmore. The strata of red sandstone and conglomerate (now known to be Cambrian, *b* of the preceding section) may be distinguished by the horizontal lines marking the stratification. The lower buttresses of the mountains are composed of the ancient gneiss with granite veins (*a* of the section).

Hugh Miller's description of these great masses of red and chocolate-coloured conglomerate and hard sandstone, which are seen reposing upon the oldest gneiss of Scotland, and which, as above explained, are overlain in their range to the north by the Lower Silurian quartz-rocks and limestones of Assynt and Durness, is so eloquent and so true that I gladly cite a portion of it. "Rising over a basement of rugged gneiss hills, that present the appearance of a dark tumbling sea, we descry a line of stupendous pyramids from 2000 to 3000 feet in height, which, though several miles distant in the background, dwarf, by their great size, the nearer eminences into the mere protuberances of an uneven plain. Their mural character has the effect of adding to their apparent magnitude. Almost devoid of vegetation, we see them barred by the lines of the nearly horizontal strata, as edifices of man's erection are barred by their courses of dressed stone; and while some of their number, such as the peaked hill of Suilvein, rise at an angle at least as steep and nearly as regular as that of an Egyptian pyramid, in height and bulk they surpass the highest Egyptian pyramid many times. Their colour, too, lends to the illusion. Of a deep red hue, which, in the light of the setting sun, brightens into a glowing purple, they contrast as strongly with the cold grey tone of the gneiss tract beneath, as a warm-coloured building contrasts with the earth-tinted street or roadway over which it rises."

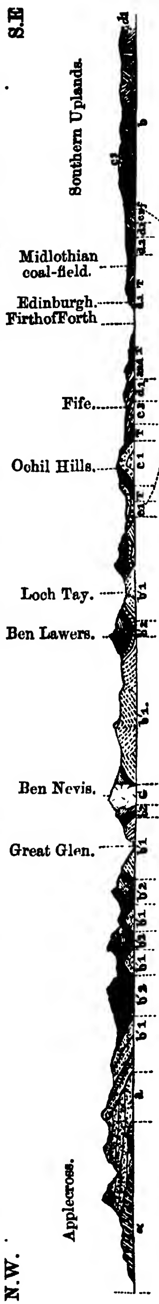
the development of the formation of Lingula-flags fills up the interval which is marked by the break in the North-west of Scotland. The Durness fossils are of the Lower Llandeilo age, and indicate a zone younger than the Potsdam Sandstone of North America, which I regard as equivalent to the Lingula-flags of England, the Alum-slates of Scandinavia, or the 'Zone primordiale' of Barrande. It is therefore a fair inference that in the North of Scotland the base of the Silurian system is represented by the lowest quartz-rock (c^1 of the preceding section, p. 169), which is seen to repose transgressively on the Cambrian rocks.

In following these metamorphic strata from Sutherland along the west coast of Ross-shire, in the years 1858, 1859, 1862, &c., I entertained no doubt that the crystalline limestones on the shores of Loch Keeshorn, Loch Carron, Loch Alsh, and Loch Duich, with the associated chlorite-schist, mica-schist, and quartz-rock, are of the same age as the lower quartz and limestone of Sutherland, like which they are also overlain by the rock mapped by M'Culloch as gneiss (c^3 of the section). To satisfy myself on this point, I traversed the lofty watershed which separates Kintail from Strath Glass, ascending from Inverinat through the striking pass the Bealloch of Kintail, to Loch Affric, and there found a vast thickness of regularly bedded gneissose, micaceous, and quartzose rocks, all of which have the same strike as the fossiliferous rocks of Sutherlandshire, and which, despite of undulations, have also a prevalent dip to the E.S.E.

The foregoing long section (p. 169) shows the general relations of all these North-Scottish rocks, from the most ancient Laurentian gneiss, through the Cambrian and Lower Silurian to the summit of the Old Red Sandstone on the eastern coast*. In addition to this illustration, it is of primary importance, towards a full comprehension of this great branch of my subject, that the reader should also have before him a diagram, drawn by my associate Mr. Geikie after our joint examination of the Highland rocks in 1862, which shows the extension of the metamorphosed Silurian strata of the Highlands by anticlinal and synclinal folds, and correlates them with their unaltered equivalents in the South of Scotland. Instead of presenting a mass of disorderly rocks from which no system could be evolved, the Scottish Highlands are found, on examination, to consist of mountains and valleys in which the same geological laws are followed as among those where the strata are in no way metamorphosed. Hence we

* In the summer of 1859 I induced my friend Professor Ramsay to accompany me to the Western Highlands to test the accuracy of the conclusion at which I had arrived respecting the separation of the younger gneiss and mica-slate from the Fundamental Gneiss, by the interpolation of fossiliferous Lower Silurian and Cambrian rocks. He not only supported me in my view, but assured me that the fundamental gneiss of my section must unquestionably be the equivalent of the Laurentian system of Logan in British North America, a survey in which country he had just made under the guidance of Sir W. Logan. Professor Nicol is the only geologist, as far as I know, who has opposed the separation of the Laurentian Gneiss from the younger gneissose rocks of the Highlands; and, in consequence of his opposition, I went with Mr. Geikie, in 1860, to reexplore the region in question. The long memoir we published (Quart. Journ. Geol. Soc. vol. xvii. p. 171), with many diagrams, has, I trust, settled the dispute. Professor Harkness, after two surveys of the Highlands, had indeed arrived at some of the same results. See Quart. Journ. Geol. Soc. vol. xvii. p. 256. This view was first placed on record by me in a Geological Map of the Highlands (Quart. Journ. Geol. Soc. vol. xv. p. 353); and subsequently it has been more closely and accurately defined in the Geological Map of Scotland, by Mr. Geikie and myself (1862).

GENERALIZED SECTION ACROSS SCOTLAND, FROM THE COAST OF ROSS-SHIRE ON THE NORTH-WEST TO THE SOUTH-EAST.



d^2. Coal-measures, Millstone-grit, and Carboniferous Limestone. d^1. Calciferous Sandstone series of the Carboniferous Formation, c^3. Upper Old Red Sandstone and Conglomerate. c^1. Lower Old Red Sandstone, conglomerate, and interstratified volcanic rocks. *b*. Lower Silurian shales and greywacké, with occasional limestone-bands, of the Southern Uplands. b'^2. Lower Silurian schists and gneissose rocks of the Highlands. b'^1. Lower or quartzose series with bands of limestone and quartz-rock, forming base of b'^2. *a*. Red and chocolate-coloured sandstones and conglomerates of Cambrian age. *α*. Fundamental or Laurentian gneiss. T. Igneous rocks, contemporaneous and intrusive. G. Granite and porphyry. *f*. Fault.

discover that the quartz-rocks, limestones, and great overlying gneissose masses of the north-west undulate in vast folds or waves across the country, until, along the Highland frontier, they pass under the Lower Old Red Sandstone. The details of this structural arrangement were sketched by my colleague and myself in the paper already referred to, and are further illustrated in the sections given along the margin of our Geological Map of Scotland. From these sections, as well as from that which he has now prepared, it will be seen that, just as the metamorphosed gneissose and slaty rocks pass under the Old Red Sandstone along the northern margin of the broad central lowlands, so from its southern margin, unmetamorphosed grits, greywackès, and shales rise from under the Coal-fields and Old Red Sandstone, and undulate in an unbroken series of anticlinal and synclinal curves up to the English Border. Hence the metamorphic rocks of the Highlands are, in all likelihood, the geological equivalents of the unaltered Silurian rocks of the Southern Uplands.

Silurian Rocks of Ireland.—Rocks which, from their included organic remains, must be classed as Silurian occupy considerable portions of Ireland, whilst certain stratified crystalline masses of this kingdom are also probably (as in the Highlands of Scotland) of the same age.

In a retrospect of the progressive steps in the classification of Irish Palæozoic rocks, allusion is first due to the veteran geologist Weaver *.

* See Trans. Geol. Soc. Lond. vol. v. p. 117; 2nd ser. vol. v. p. 1 *et seq.*

The earliest publication, however, in which any of the fossils of very ancient date were illustrated was the valuable detailed Survey of parts of the North of Ireland by the late General Portlock, who, from a small district of schistose greywackè, near Pomeroy in Tyrone, described a multitude of interesting types, which enabled him distinctly to class these strata with the Lower Silurian group *.

When the first edition of Griffith's great Geological Map of Ireland appeared, the existence of rocks containing fossils of this age had been ascertained in a few localities only, the term Silurian being restricted by him to the precise spots from which those organic remains were obtained; and an important work on the 'Silurian Fossils of Ireland' was printed in 1846, under his auspices. But the progress of research, of late years, on the part of Sir Richard Griffith and his assistants, has much extended the areas in Ireland in which Silurian fossils occur, and has prodigiously increased the lists of organic remains.

The labours of the Government Surveyors, first under Professor Oldham, and now directed by Mr. Jukes, have since led to a still more methodical elucidation of these rocks. In this way it has been ascertained that in the one term of 'greywackè,' the following masses were grouped:—First, the Cambrian or dull-red and purplish schist and grey quartzite, to the south of Dublin, the equivalent of the Longmynd, in which no other fossils, as before stated, have been found, except Fucoids and two species of Oldhamia (p. 29). Occupying the headlands of Bray, the mountains of the Sugarloaf, and the gorge of the Dargle, to the south side of Dublin Bay (and probably many other parts of the kingdom), these older or bottom rocks have recently been determined to be overlapped unconformably by all the overlying fossiliferous strata to which the term Silurian has been applied. With this physical severance, so completely in contrast to the order of succession in Shropshire and North Wales (p. 31), there is, as might be expected, an absence in Ireland of the band of Lingula-slates, which in other countries occupies the intermediate horizon.

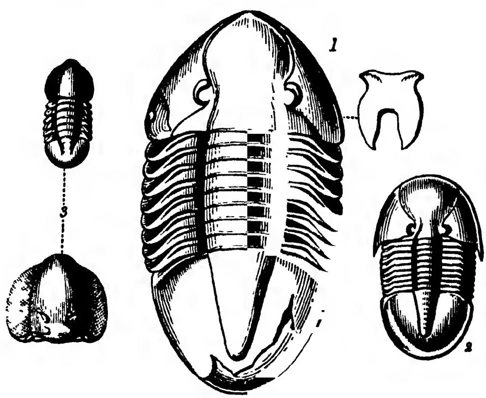
The first recognizable strata which overlie the purple schists with Oldhamia are dark slaty strata which at intervals are found to contain undoubted Lower Silurian remains. These fossiliferous schists occur in large but broken bands in the counties of Wicklow and Wexford, and reappear from beneath the Old Red Sandstone and Carboniferous Limestone in the cliffs of Waterford to the south of the Bay of that name. Flanked as these Lower Silurians are, on their western side, by the dominant ridges of eruptive granite that form the Wicklow Mountains, they are there either in a crystalline or subcrystalline state, and thus exhibit a third condition of the greywackè of old authors, which in the new maps of the Geological Surveyors is distinguished by a darker tint.

The silvery sheets of the well-known waterfall of Powerscourt are pre-

* See Report on Londonderry and parts of Tyrone and Fermanagh. Dublin, 1843.

cipitated over highly inclined crystalline chloritic and micaceous schists of this class, which in Ireland are probably the equivalents of the crystalline rocks of Anglesea (see p. 35). In the central parts of the South of Ireland, or on the western side of the granite of the Wicklow Hills, the limestones and schists of the Chair of Kildare, which are replete with fossils, or the schists on the flanks of the Slieve Bloom Mountains, are classed as Lower Silurian*; so also are several masses of these rocks at Portrane to the north of Dublin, and especially near Pomeroy in Tyrone, the richly fossiliferous locality just stated to be the first clear Silurian type described in Ireland †. It is truly remarkable that so many of the characteristic Lower Silurian fossils should have been detected by the late General Portlock in this small tract and another, of no larger dimensions, in Fermanagh. Several of the Trinuclei and other Trilobites, such as Phacops, Calymene, and Illænus, are identical in species with those of Caradoc (or Bala) age from Shropshire and Wales; and so is it with the simple-plaited Orthidæ, Leptænæ, and Strophomenæ, some Spiral Shells, and many Orthocerata (Plates I.–XI.). Commingled, however, with these are peculiar forms which were first made known from this district, and are very rare indeed in any other tract of the British Isles. Such, for example, are the Trilobites figured in the Tenth Chapter, the Remopleurides, Harpes, Amphion, and Bronteus. Such also are the smooth forms of Asaphus, called Isotelus by American authors, which in Ireland, and on the other side of the Atlantic, are very abundant, whilst they are exceedingly rare in Wales or England, and are not known on the Continent ‡.

FOSSILS (29). LOWER SILURIAN TRILOBITES, IRELAND.



1. Asaphus (Isotelus) gigas, De Kay; and its labrum.

2. Stygina latifrons, Portl.
3. Ægina mirabilis, Forbes.

In Wexford, Waterford, and at the Chair of Kildare, the older strata have been so much disturbed and insulated that it is difficult to detect

* It is believed that the schists of Down may prove to be of the same age as the graptolite-schists of the opposite Scotch counties of Wigton, Galloway, Ayr, &c.

† I examined this tract in company with that experienced Irish geologist, Mr. John Kelly.

‡ A new species of Phacops (P. Nicholsoni, Salter) has been found in these Caradoc rocks of Tyrone (Quarterly Journ. Geol. Soc. vol. xxii. p. 486).

anything like a sequence of order. Still the fossils, together with the physical characters of the rocks, clearly mark the Lower Silurian era. In the cliffs on the banks of the River Suir, below Waterford, and in the coast headlands of Newtown near Tramore, and of Bon Mahon*, the schists with feeble impure concretionary limestones are underlain by schists which at Waterford are probably of Llandeilo age, the fossiliferous beds on the coast being rather referable to the Caradoc formation. These strata are charged with the simple-plaited Orthidæ, Trilobites of the genera Trinucleus, Ogygia, and Phacops, Double Graptolites (Diplograpsus), and Corals, in as great abundance as in strata of the same age in Wales and Scandinavia.

In the western districts of Cork and Kerry, I satisfied myself, by two visits, that the masses of hard, purple and greenish grits and slaty rocks which rise into the loftiest mountains of Ireland around the Lakes of Killarney (Macgillycuddy's Reeks, Mangerton, &c.), and range to the Island of Valentia, are all of Devonian age. This is proved by the fact that in the promontory of the Dingle these rocks distinctly overlie and pass down into strata charged with true Upper Silurian fossils. Many of these organic remains had indeed long been known, some of them having been figured and described by M'Coy from the collections of Sir R. Griffith, with whom I first visited the district in 1842.

At that time, however, the exact order of the rocks occupying the great mountainous mass of land lying between the Bays of Dingle and Tralee had been little examined. Still, even then, Professor Phillips and myself had come to the conclusion that a great portion of these mountains must belong to the Devonian system, since it was evident, even on a first traverse, that these strata rose up from beneath the lowest Carboniferous Slate and Limestone.

The nomenclature which Sir R. Griffith was formerly induced to adopt respecting these south-western tracts, though now changed, was very rational. Seeing vast masses of chloritic and quartzose schists and other bands of very ancient-looking rocks that were in certain tracts unconformably surmounted by red conglomerates and sandstones, which latter he knew to be inferior to everything Carboniferous, that vigilant and indefatigable observer naturally grouped the first-mentioned of these as Silurian, and so at first coloured them in his excellent Geological Map of Ireland.

Now a chief portion of the rocks which Griffith termed Silurian were those mountain-masses which are splendidly exhibited near Glengariff, and roll over in the lofty undulations around the Lake of Killarney before

* Most of the fossils described by Mr. Weaver in his memoir on the South of Ireland, Trans. Geol. Soc. Lond., 2nd ser., vol. v. p. 1 *et seq.*, are now known to pertain to the Carboniferous system; but certain localities which he notices, such as Smerwick Harbour or Ferriter's Cove, and Bon Mahon, near Waterford, which he termed 'transition,' were long ago recognized by Sir R. Griffith and his assistant, Mr. John Kelly, to be Silurian, though with no precise reference to their age. In the public collection in Stephen's Green, Dublin, and in the rich cabinet of Sir R. Griffith, the geologist will find an instructive assemblage of these Lower Silurian (Caradoc) fossils of Waterford.

alluded to, reappearing in the promontory of the Dingle. Traversing these tracts from Bantry to Killarney in 1842, I even then, I repeat, came to the conclusion that all these rocks must form a large portion of the Devonian system; for, together with certain red conglomerates and sandstones which overlie them, they are seen in several synclinal troughs to lie below the very base of the Carboniferous system.

It was, however, still requisite to explain the physical relations of these masses to the well-known fossiliferous Silurian deposits of Ferriter's Cove, Smerwick Harbour, and other places in the Dingle district. Were the Glengariff grits and Macgillicuddy's Reeks really superior to the Silurian Rocks of the Dingle?

To solve this question, Mr. Du Noyer made a detailed survey, and in August 1856 I revisited that ground, accompanied by Sir R. Griffith, Mr. Jukes, and Mr. Salter, to endeavour to detect the real physical relations of the fossil-bearing Silurian rocks to the great schistose and quartzose masses termed the 'Glengariff grits' *.

However difficult we found it to fix upon the precise spot where the oldest of the Silurian fossils could be detected †, it was quite manifest that in the westernmost headlands, Ferriter's Cove, Smerwick Harbour, Clogher and Doonquin Bays, there were unquestionable Wenlock remains in abundance, and that the strata containing those fossils were overlain by an unequivocal representative of the Ludlow rocks, in which, though the strata are to a great extent lithologically different from those of the Silurian region, the same typical species of fossils occurred as in rocks of the same age in England and Wales.

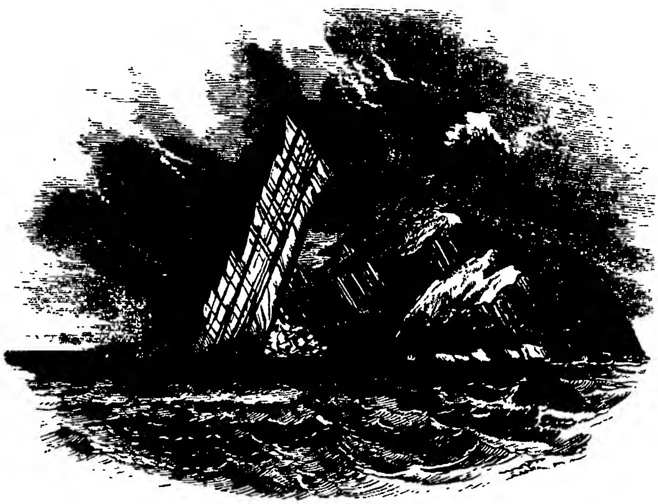
Notwithstanding the obscuration of the interior country, these facts are plainly set forth, particularly in the coast-cliffs between the Sibyl Head and Dunmore Head, which face the Blaskett Islands. There the Silurian strata occupying ledges on both sides of Ferriter's Cove, contain Wenlock fossils. To the north these are succeeded by pale purple unfossiliferous sandstones, including some lenticular beds of conglomerate; and these are overlapped unconformably by the younger part of the Old Red sandstone and conglomerate, the beds of which rise into the rugged Sibyl Head to the height of 670 feet above the sea.

When, however, we follow the Silurian rocks to the south along the coast to Clogher Bay, and thence to Doonquin, we meet with a true ascending order, after a great fold in the beds at the Clogher Head. A series of green, grey, and purple schists and sandstones containing semicalcareous and nodular bands, and associated with much interstra-

* This term, 'Glengariff grits,' was suggested by Mr. Jukes; and in the last published maps and sections they are included by him in the Old Red Sandstone (according to my view, Devonian).

† In one locality, however (the small cove called Coosathurig, under the Bull's Head promontory to the east of Dingle), certain species were found which Mr. Salter considers definitely to indicate a passage downwards from rocks with true Wenlock fossils into the Pentamerus or Llandovery rocks. At this spot occurs a Pentamerus (apparently identical with P. oblongus), Palæocyclus porpita, Favosites and Heliolites, and many large hollow-stemmed Encrinites, which are very characteristic of the Llandovery rocks. Further collections are much wanted from this wild spot.

tified volcanic ash and bosses of igneous rock, is there found to be charged with typical Wenlock fossils. These are Euomphalus funatus and other species of that genus, Spirifer bijugosus, Rhynchonella nucula, Orthis elegantula, Atrypa reticularis, Proetus latifrons, with numerous Corals,

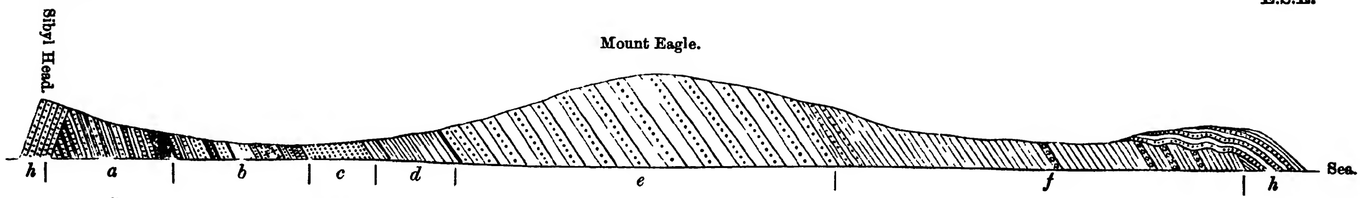


THE SIBYL HEAD (SEEN FROM THE WESTERN OCEAN).
(Sketched by Mr. Du Noyer, of the Geological Survey.)
The strata rising up to the highest point, Sibyl Head, consist of Upper Old Red sandstone and conglomerate. The lower ledges are Silurian.

including the Chain-coral, also the Trilobites Phacops caudatus and Encrinurus punctatus. In the same strata we also find Chonetes lata in abundance, whilst in England it is the typical fossil of the Upper Ludlow rock.

The beds which contain contemporaneous volcanic grit, and occasionally intrusive greenstones, are overlain by strata which are best exposed inland; and in these (as between Doonquin and Croagh-marhin) there are many true Ludlow rock and Aymestry fossils—such as Pentamerus Knightii, Rhynchonella Wilsoni, Rh. navicula, Avicula reticulata, &c., together with Calymene and the small Lichas anglicus. In truth, however, the geologist would scarcely be able to draw those distinctions between the Wenlock and Ludlow rocks which are traceable in Siluria, but for the occurrence of a band of red slate and a thick development of fucoidal sandstones, which here form the base of the Ludlow rocks. These fucoidal strata are well seen in Clogher Bay and Smerwick Harbour, their physical relations and organic characters having been traced out by Messrs. Du Noyer and Salter. In the overlying beds with Pentamerus Knightii and Cardiola interrupta, there are numerous species of Corals,

DIAGRAM SHOWING THE ORDER OF THE ROCKS OF THE DINGLE PROMONTORY.



Silurian. Lower Devonian.

(Old Red Sandstone.)

UPPER DEVONIAN.
- *h, h.* Overlying red and purple conglomerate and sandstone, which rest unconformably on the inferior rocks, but pass conformably in the eastern part of the promontory under the base of the Carboniferous series. This is the Upper Old Red,—the Middle Devonian, or Caithness Fish-beds of the Scottish Old Red Sandstone, and the fossiliferous limestones of the Eifel and Devonshire having no equivalent in this section.

LOWER DEVONIAN.
- *f.* Purple grits, sandstones, and slates, containing in their upper portion bands of brightly coloured slates and flags, ripple-marked and sun-cracked, with conglomerates, some of the pebbles of which are rolled pieces of calcareous rock containing Pentamerus oblongus, Encrinurus punctatus, and other Silurian fossils. No fossils except in these pebbles. Apparent thickness 4000 feet.
- *e.* Thick-bedded massive grits and sandstones, with bands of green and purple slate; the grits obliquely laminated, often conglomeratic, and containing calcareous layers. No fossils known. Thickness about 8000 feet.

UPPER SILURIAN.
- *d.* Alternations of green and purple slates without fossils, terminating in beds of purple cornstone; about 1500 feet. Passage-beds.
- *c.* Green, brown, and grey flags and slates, containing Ludlow fossils; about 1000 feet.
- *b.* Alternations of pale-green or grey and dull-purple slates and purple-brown grits; succeeded by grey flags and slates with alternating beds of felspathic trap and ash; upper portion of group consisting of a thick deposit of felspathic grits, terminated by a bed of greenstone. Over all, a series of purple grits and slates with thin ash-beds. Wenlock fossils. Thickness 2500 feet.
- *a.* Red and salmon-coloured sandstones and beds of conglomerate. No fossils.

including a fine branched form of Heliolites, allied to H. inordinatus, Lonsdale. The curious Annelide-tube, Trachyderma squamosum, Phill., is found also in these beds and in a vertical position; it is a species found in the Ludlow rock.

The highest of the strata in which such fossils occur are purple-coloured and yellowish flag-like sandstones; and these are seen to pass gradually and conformably upwards into the greenish and purple slaty beds forming the base of the great series termed 'Glengariff grits and schists,' which, not less than 7000 feet thick, occupy Mount Eagle and a long range of the Dingle coast. These beds are in their turn conformably surmounted by a thick suite of purple sandstones and conglomerates, containing pebbles and fossils derived from the underlying Silurian limestone.

As, then, all these rocks distinctly overlie and pass upwards gradually from strata charged with Upper Silurian fossils, there can be no hesitation in considering them to be the representatives of those slates and grits which, in Germany, Belgium, and North Devon, form the lowest portion of the Devonian system.

The preceding diagram, as prepared by Mr. Du Noyer, exhibits the general relations of the Silurian rocks of the Dingle promontory (*a*, *b*, *c*) to the great and superjacent masses of Old Red Sandstone, whether they consist of the passage-beds (*d*), the 'Dingle' and 'Glengariff grits' (*e*), red sandstones and conglomerates (*f*), or the overlying Upper Old Red Sandstone (*h*). These equivalents of the Devonian rocks will be commented upon in the next chapter. In the meantime it is enough to point out that the Upper Silurian and Ludlow fossils entirely terminate with the yellow-green and purplish sandstones (*d*), the latter being surmounted by rocks in which no organic remains have yet been discovered.

In travelling along the west coast, or by the Carboniferous rocks of Clare, to the county of Galway, the geologist again meets with tracts which are replete with Silurian fossils. Lying to the north of the picturesque mountains known as the Bins of Connemara, these fossil bands, of rather older date than the Dingle Silurians, occupy the bold and precipitous sides of the deep Bay of Killery, and range over a considerable space eastwards, by Leenane, Maam, and Oughterard, to the shores of Loughs Corrib and Mask.

Whilst on the eastern side of Ireland the eruption of the granite of the Wicklow Mountains has metamorphosed, as before said, the contiguous Lower Silurians, so in Connemara, on the west, we have a still more striking example of metamorphism, of a very large mass which, in my opinion, must be also considered Lower Silurian. The following diagram is reduced from one of Sir R. Griffith's coloured transverse sections across this remarkable district. After a personal survey of most of the Silurian tracts of Ireland, it has appeared to me best adapted to explain how certain crystalline rocks, which from their mineral aspect have hitherto been supposed to be of higher antiquity, are (like the Highland rocks before

SECTION ACROSS THE BINS OF CONNEMARA, AND KILLERY HARBOUR. (From Sir R. Griffith's coloured section, prepared by Mr. Ryland Byron.)

Metamorphic Lower Silurian Rocks. Fossiliferous Silurian (Llandovery) Rocks.

a. Metamorphosed lower slaty rocks with white, green, and grey crystalline limestone (Connemara marble). *b.* Hard quartz-rocks passing into flagstones and courses of grey limestone, subordinate to mica-schist in a tract not traversed in this section. This limestone resembles that of Inverary and Loch Fyne in Scotland. *c.* Silurian rocks composed of conglomerate and dark schist, slightly unconformable in this traverse to the underlying metamorphic rocks, but in other places completely discordant. *d.* Trough of conglomerate and purple sandstone; numerous Silurian (Llandovery) fossils in several localities. *. Igneous rocks, granite. †. Porphyry and greenstone.

described) nothing more than the altered lower members of the sedimentary deposits under consideration.

In proceeding from Roundstone Bay on the south, low isles and headlands of granite, *, followed by syenitic and hornblendic rocks, †, throw off highly altered micaceous and quartzose schists, with courses of white and grey crystalline limestone, *a*, which, as you ascend the mountain of Ben Glenisky, one of the Twelve Bins of Connemara, are seen to be followed by strong masses of granular, white quartz-rock, *b* (manifestly an altered sandstone), which alternate with mica-slate.

Interlaced in the lower part of this series, and lying in depressions between Ben Glenisky and Ben Bawn (2300 feet above the sea), and thence ranging to the west, are certain crystalline limestones, one course of which is grey and white, and another is the beautiful green marble or serpentine of Connemara. They are overlain by the granular quartzites and mica-slates, *b*, which, occupying the greater portion of these mountains, are in some places surmounted on their northern face (with a slight unconformity ‡ only) by

‡ In a traverse of this tract, which I made from Clifden to Killery Bay, in the company of Professor Nicol, the green marble seemed to me to be enclosed in mica-schist and quartz-rocks. We also, however, met with a grey limestone, sub-

conglomerate, sandstone, and schists, *c*, containing fossils, as at Lettershanbally, Blackwater Bridge, Leenane, Maam, and other places. Now these remains, all unequivocally Silurian, belong by no means to the lowest members of the system. On the contrary, though some of them are found elsewhere in the Lower Silurian strata, their prevalent species refer the beds rather to the Llandovery or intermediate rocks. In fact the strata resemble, both zoologically and lithologically, some of the upper fossiliferous greywackè before described on the banks of the Girvan Water, in Ayrshire; many of the same species occurring in the two districts. Several of the Irish fossils are, indeed, more common in the Upper Silurian, both of England and Wales.

Some of the remains in the beds near Maam would be considered Lower, and others Upper Silurian, there being among the latter Bellerophon trilobatus, first published from the Tilestones or summit of the Ludlow rocks. With the widely spread fossils Strophomena depressa and Atrypa reticularis, which occur in nearly all the Silurian strata, we here met with Pentamerus oblongus, Orthis calligramma (virgata), O. reversa, Atrypa hemisphærica, &c., which elsewhere are known only in rocks of Llandovery age, associated with Rhynchonella Wilsoni and Retzia cuneata, Bellerophon trilobatus, and some Lamellibranchiata, such as the Pterinea retroflexa and Cucullella antiqua, which were long ago described as true Upper Silurian fossils. Here, also, in the beds of junction with the mica-slates, are the Chambered Shells Cyrtoceras approximatum, Orthoceras bullatum, O. ibex and O. angulatum,—species formerly supposed to mark the Upper Silurian only, but since found also in some of the lower strata. Among the Trilobites we have even our persistent friend Calymene Blumenbachii, that ranges from Snowdon to Ludlow, and Encrinurus (Amphion) punctatus, together with the genus Stygina, only yet known in Lower Silurian strata, and apparently the same species which is found in Tyrone, and Cyphaspis megalops, a Dudley fossil. Again, the Corals from another locality (Kilbride) present us with such species as Favosites cristatus, F. Gotlandicus, F. multiporatus, &c., which are usually Upper Silurian types *.

To sum up, then, we have seen in Dingle a copious and unmistakeable series of true Upper Silurian rocks and fossils, surmounted by Lower Devonian schists, slates, grits, and sandstones. In Connemara and the adjacent tracts, and thence extending to Uggool in Mayo, the intermediate group of Llandovery rocks is strikingly apparent, though in fragments and patches only; whilst a multitude of organic remains, whether they be the well-defined forms

ordinate to the upper portion of the mica-schist, which, as in Argyleshire on both sides of Loch Fyne, exhibits many of the appearances of ordinary stratified limestone, in respect to bedding, joints, and way-boards; but we could detect no fossils in it. The above section exhibits the strata, *c*, containing Silurian fossils, reposing unconformably on these micaceous rocks; and there are many other such junctions (as around Maam) where the relations are quite discordant.

* This enumeration of fossils was given in the previous edition. Since then Prof. Harkness has gone over the same ground, and his observations confirm my conclusions. (See Quart. Journ. Geol. Soc. vol. xxii. p. 512.)

described by Portlock from Tyrone, or those of the fossil-bearing schists of Kildare, Wexford, and Waterford, are unquestionably Lower Silurian, and, for the most part, of the Caradoc age. Where, then, is the lowest Silurian in Connemara and other tracts in which metamorphic rocks appear beneath the fossiliferous strata? My belief is, that the lower group is represented by the great underlying crystalline masses of the Bins of Connemara, and that the limestones included in those mica-schists are nothing more than the Lower Silurians altered, some of them being of the age of Llandeilo, and others the equivalents of the Caradoc rocks. Recently the announcement of the existence of an Eozoon in the serpentinous green marble of Connemara seemed to lead to the opinion that these rocks were of Laurentian age. But even if it should be proved that the Foraminifer is present, its occurrence would in nowise affect my conclusion that the rock is Lower Silurian. The truth is, that, independently of the fact that the crystalline rocks of Connemara immediately underlie the Llandovery rocks, the succession of quartz-rocks, limestones, and mica-schists is exactly similar to that of the Highlands of Scotland, before described. Professor Harkness ‡ has ably pointed out this analogy, and has shown that these Irish rocks are simply prolongations of the Scottish-Highland series. As already explained, the presence of an Eozoon (if that be admitted) has really little bearing on the question; for creatures of that low type of life may, as before said, well have lived on from the Laurentian to the Lower Silurian epoch.

In the Galway tract we cannot, indeed, pursue a clear ascending order, any more than in Scotland, though it is possible that a succession like that of the district of Dingle may be detected. As yet it has only been observed that a coarse, chloritic, quartzose conglomerate overlies the fossiliferous beds in question—a conglomerate which, according to Mr. Griffith, rises into mountainous masses on the north side of the Killery Bay. Alternating with green and purple slates and interstratified felspar-porphyries (†), these upper rocks, after an undulation, repose upon a vast mass of greenish, grey, and reddish slate (*c*). The base of the fossiliferous series to the north of the Killery Harbour is composed of a dark and reddish-brown sandstone, under which is a conglomerate of mica-schist and other rocks, the whole resting, as on the other side of the trough, on mica-schist (*b*). (See section, p. 180.) Then follows a boss of granite, * (Knockaskeheen), which throws off crystalline schists on both flanks,—the masses in the north being bounded by the unconformable and horizontal Carboniferous Limestone of Clew Bay in Mayo.

Seeing that we cannot there trace downwards fossils of higher antiquity than the middle portion of the Silurian series, it seems fair to infer that the subjacent quartz-rock, mica-schist, and stratified limestone of Connemara are really the representatives of the Lower Silurian rocks.

The progress of research will also, I trust, bring out other evidences to

‡ Quart. Journ. Geol. Soc. vol. xvii. p. 256.

support the views respecting metamorphism derived from a survey of the Connemara tract, and which, after the proofs of an Upper Silurian series obtained in the Dingle district, seem to be rendered still more probable. May not, indeed, this view of the metamorphism of Lower Silurian rocks be applied to some of the crystalline rocks of Donegal? and may they not eventually be brought into connexion with the true Lower Silurian oasis of Fermanagh and Tyrone? This is a task worthy of the Irish Government Surveyors, and which, I have no doubt, they will ably accomplish. No one who has examined the small patch near Pomeroy could imagine, from the aspect of the schists, that it would have proved so highly fossiliferous as it did under the scrutiny of the lamented General Portlock. Hence we need not despair of finding the occupants of other former burying-places in various parts of the large area of Ireland over which Silurian rocks are believed to extend, though these deposits, being to so great an extent metamorphosed, are necessarily sterile in organic remains.

Some of the most characteristic of the Irish Silurian fossils will be noticed in the two ensuing chapters; but a full acquaintance with them must be sought for in the works of Portlock and M'Coy, and in the tables of Sir Richard Griffith's map.

Note.—Mr. Jukes has forwarded to me a description of a band of anthracitic coal, which occurs in ancient clay-slate and hard grits at Kilnaleck in the county of Cavan, and to which my attention was formerly directed by Mr. Kelly (see Appendix to first edition, p. 493). The strata in which this anthracite lies extend from Cavan through the counties of Louth, Monaghan, Armagh, and Down; and, from their composition as well as from their strike to the N.E., they are supposed to be of the same age as the anthracitic Lower Silurian schists of Dumfriesshire in Scotland already described (p. 152). This course of Irish anthracite, which varies in thickness from 1 to 12 feet (ranging, in a nearly vertical position, with its associated beds, from S.W. to N.E.), is a fuel of better quality (in short, a real coal) as well as of larger dimensions than any similar substance hitherto noticed in the Silurian rocks.

Review of the Silurian Rocks of the British Isles.—In concluding these observations on the Silurian rocks of Britain, let me specially call the attention of the reader to the direct bearing which the discovery of Lower Silurian fossils in Sutherland must have in determining the true geological age of a very large portion of the stratified crystalline rocks of the western and central Highlands.

It is, indeed, gratifying to me to find that my original theoretical view, repeated in previous editions of this work, seems now to be fully sustained—viz. that the great mountainous expanses of argillaceous, chloritic, micaceous, and gneissic schists, with intercalated quartz-rocks, marble, and limestones, which constitute the chief portion of the so-called primary rocks of the west of Scotland, and extend from Dumbartonshire, through Argyllshire and Inverness-shire, into the central and eastern parts

of Ross-shire and Sutherland, are on the whole the metamorphosed prolongations of the Lower Silurian rocks of the South of Scotland.

We now further know that these crystalline masses of Lower Silurian age overlap those red sandstones and conglomerates which, much older than the Silurian red conglomerate of Ayrshire (p. 155), are doubtless the equivalents of the Longmynd or Cambrian rocks; whilst the latter repose upon ancient Laurentian gneiss, which is nowhere exhibited in England and Wales.

Taken then as a whole, the natural sections of the British Isles sustain the view put forth in the earlier pages of this volume, which presented to the reader the general order of the primeval rocks*.

Vertical Dimensions of the Cambrian and Silurian Rocks of the British Isles.—We have as yet no means of calculating, even approximately, the thickness of the older deposits of Scotland and Ireland which have been treated of in this Chapter. In both regions large spaces occur throughout which the framework of the subsoil is so obscured and hidden that it has not yet been ascertained whether there is a continuous ascending order, or if the same strata be repeated by flexures the upper portions of which have been cut off.

In the typical region of Shropshire and the adjacent Welsh counties, as described in the preceding Chapters, we can, however, appeal to the estimates of the Government Surveyors. In Shropshire, the Longmynd rocks (the 'Cambrian' of the Survey) are supposed to have the vast thickness of 26,000 feet, or about three times that of the same strata in North Wales; but even admitting that these rocks are to some extent repetitions (of which, however, I see no evidence), their dimensions, according to any estimate, must still be enormous.

The Lower Silurian strata of Shropshire to the west of the Longmynd, from the Stiper Stones upwards, including the Llandeilo formation, exhibit a thickness of 14,000 feet; and if we add to this mass the thickness of the Caradoc sandstones, limestones, and shales lying on the eastern slopes of Caer Caradoc, which have been described at p. 66, and amount to about 4000 feet, we ascertain that in the typical tract of Shropshire alone the Lower Silurian rocks attain the dimensions of 18,000 feet. These dimensions are, indeed, nearly equal to those which have been estimated for their equivalents in the lofty, slaty, and rugged region between the Menai Straits and the Berwyn Mountains, where the Surveyors have estimated the total thickness of all the strata of like age at 19,000 feet.

In the Cambrian or lowest part of these enormous accumulations of sedimentary strata, rare traces only of fossils have been found; but in the Lingula-flags (the 'primordial' of the Silurian zones) organic remains increase sensibly, and of late years many new forms have been detected

* See the generalized diagram at p. 24, in which Laurentian gneiss is represented as the fundamental rock, though not seen in the Silurian region of England and Wales.

in them. It is, however, in the Llandeilo and Caradoc formations that Trilobites, Mollusks, and Corals augment enormously and amount to many hundred species.

The Llandovery rocks, intermediate between the lower and upper divisions, swell out in some parts of Wales to a thickness of 2000 or 3000 feet; and, though in many tracts this zone is of small dimensions, it is not poor in the variety of fossil species.

The Upper Silurians, consisting of Wenlock and Ludlow rocks, attain nowhere a greater thickness than 5000 or 6000 feet; and yet this younger group is as replete with fossils as the Lower Silurian strata, the dimensions of which are so much larger.

In conclusion, it is, indeed, well to reflect upon the fact that, notwithstanding their enormous physical development (of not less than 26,000 or 27,000 feet), the British Silurian rocks are scarcely more copiously charged with organic remains than the strata of the same age in Scandinavia, where the total united thickness of the Lower and Upper Silurian does not exceed 2000 feet, as will be shown in a subsequent chapter.

CHAPTER IX.

ORGANIC REMAINS OF THE LOWER SILURIAN ROCKS.

A FULL acquaintance with the Silurian Fossils of the British Isles can be gained only by a study of the various works in which they have been successively described. Of these works, the first in which the fossils were classified and placed in their true geological position is the 'Silurian System'*; the next is a Report on the Silurian fossils of Tyrone, by Portlock; a third, on the Silurian fossils of Ireland, by M'Coy. Then follow various publications of the Government Geological Survey, particularly the volume on the Malvern and Abberley Hills, by Professor Phillips and Mr. Salter, certain monographs descriptive of both Lower and Upper Silurian forms, in the Decades of the Geological Survey, by the late Professor E. Forbes and Mr. Salter, and the Appendix by Mr. Salter to Professor Ramsay's 'Geology of North Wales' (Mem. Geol. Surv. vol. iii.). Notices of Silurian fossils have also been published by Mr. D. Sharpe, Mr. Salter, and other writers in the volumes of the Quarterly Journal of the Geological Society of London. A detailed description of the Upper Silurian Brachiopods, by Mr. Davidson, appeared in the Bulletin of the Geological Society of France, nearly all the British species being there figured and described. In the Introduction to his Monograph of British Fossil Brachiopods (vol. i.), Mr. Davidson has described their generic characters; and his special Monograph on the Silurian Brachiopods, published by the Palæontographical Society, is a work of the highest order of merit. Three parts of Mr. Salter's Monograph of the British Trilobites have also been published by the same Society. Professor Rupert Jones has described most of the small Bivalved Crustaceans of the Silurian rocks, in the 'Annals of Natural History.' Lastly, an important addition has been made to our knowledge of the British fossils of this age through the publication, by Professor Sedgwick, of Professor M'Coy's descriptions of the Palæozoic fossils in the Woodwardian Museum of Cambridge. This work, to which references are often made in the present volume, contains elaborate descriptions of upwards of 300 species, with figures of the new forms.

The reader who consults these various works† will find that, whilst a marked division was at first particularly insisted on, by myself, as existing between the Lower and Upper Silurian, subsequent researches, extended over large areas, have shown that the two groups are much more closely knit together in one natural series than was formerly supposed,—it being now well ascertained, as already explained, that a considerable

* The Shells of the 'Silurian System' were described by James de C. Sowerby, who had previously figured and described some of the species in his 'Mineral Conchology.' The latter were chiefly from the Wenlock Limestone.

† In the 'Geologist,' vol. i., 1858, Prof. Morris published a very useful List of Books and Memoirs relating to Silurian and Cambrian Geology, complete to that date.

number of characteristic fossils are common to the inferior and superior members of the system, and that the two are zoologically united through the intermediate 'Llandovery rocks.' In the course of the observations which follow, this generalization will be placed in a clearer point of view.

In the earlier Chapters of this work, the fossils of the Longmynd rocks, the Lingula-zone, and the lower part of the Llandeilo strata have been much adverted to. In describing the succeeding formations, however, the typical species alone have been cited; and it is now desirable to give a more complete view of the general characters of the chief mass of the Lower Silurian fauna, or of the Llandeilo and Caradoc formations.

Among the organic remains of the Lower Silurian rocks, Graptolites have been already often alluded to, being Zoophytes exclusively characteristic of the Silurian era (see p. 61) and which must have inhabited a sea with a muddy bottom. Of those forms which specially mark the Lower Silurian rocks, the Double Graptolite (Diplograpsus) and the Twin Graptolite (Didymograpsus) are the most common in Britain. Diplograpsus pristis, p. 51, Foss. 10. f. 15, ranges from the base of the Llandeilo flags to the Caradoc sandstone inclusive; D. folium, p. 61, Foss. 12. f. 6, is common in the anthracite-beds of Scotland (as well as in the Alum-slates, or Lingula-zone, of Sweden); and there are several other forms found in Scotland and Wales.

There is a curious half-branched species, Diplograpsus ramosus, Hall, figured Foss. 12. f. 7, which seems to lead off to the Twin Graptolite, Didymograpsus, of which we have several species in England. Of these, D. Murchisoni, Beck, Foss. 12. f. 9, is one of our commonest Welsh species. The North-American forms, D. sextans of Hall (Foss. 12. f. 8), and D. Moffatensis, Carruthers, and the Continental D. Forchhammeri, Geinitz, are found in the South of Scotland; and there is yet another two-winged Graptolite (probably the same as a Canadian species, D. caduceus, Salter) in the slates of Wexford.

A form of the North-American genus Phyllograpsus, Hall, which has a large axis and two or four very broad celluliferous plates, has been found in the Skiddaw Slates. The species that have a greatly produced and frequently branched stipe are represented by two species from the Llandeilo rocks—the one, Dendrograptus linearis, Carr., from Scotland, the other, D. gracilis, Hall, from Ireland; and a third species, D. involutus, Carr. MS., occurs in the Wenlock shales at Builth. The species with four, eight, or more branches proceeding from a single axis, which have been discovered by Sir W. E. Logan in Canada (Dichograpsus, Salter), are represented by three species from the Skiddaw Slates; but no indication of the singular disk that occurs in the Canadian species has been observed in any of them.

Of the simpler forms, those with teeth on one side only of the branches, Rastrites and Graptolithus, the former is abundant in North Britain, where also the Graptolithus priodon, Pl. XII. f. 1, occurs in plenty, though not quite so low in the series. This last fossil ranges from the Lower Silurian to the Upper Ludlow rock.

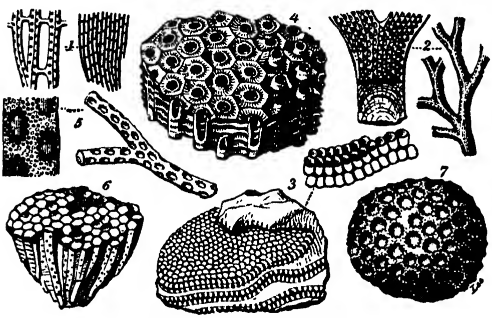
Opinion has been divided among naturalists as to the true position of Graptolites in the animal kingdom. Of late they have been generally regarded either as Zoophytes of the Alcyonarian or the Sertularian orders, or as belonging to the Polyzoa (Bryozoa). If the organisms described by Mr. Nicholson (Geol. Mag. iii. p. 488) are really ovarian vesicles of Graptolites, this observation strengthens the

view of their Sertularian affinities; but that they were Polyzoa some think the more certain on account of the discovery of a form intermediate between them and the Fenestellæ.

This is the Dictyonema (or Phyllograpsus, as it has been called by Prof. Angelin), which, as already noticed, p. 45, occurs in the Lingula-flags of Wales and Shropshire. It combines with the shape and general characters of the net-like Polyzoa, the texture and the form of the cells of the Graptolite, and may be regarded as a bundle of these animals united by processes into a reticulated cup. The curiously complex branched forms of Graptolites discovered by Sir W. E. Logan in Canada seem to complete the chain of affinities between the Graptolites and the Fenestellidæ.

Besides these inhabitants of ancient muddy seas, which are, as before said, exclusively Silurian in all quarters of the globe, many forms of true Polyzoa are seen even in the lower portion of these deposits, and are abundant throughout the series. These were formerly confounded with Corals, and in the eye of the field-geologist might still pass for such, though they are really low forms of Mollusks, having even no distant affinities with the Brachiopoda! They are here associated in the same woodcuts (Foss. 30 & 31) with the Corals.

FOSSILS (30). LOWER SILURIAN ZOOPHYTES AND POLYZOA.



1. Fenestella subantiqua, d'Orbigny.
2. Ptilodictya acuta, Hall.
3. Nidulites favus, Salter*.
4. Sarcinula (Syringophyllum, Milne-Edw. and Haime) organum, Linn.
5. Heliolites inordinatus, Lonsdale.
6. Favosites Gotlandicus, Goldfuss.
7. Heliolites megastoma, M'Coy; a species with large cells, found in Pembrokeshire.

The species with a net-like form, Fenestella and Retepora, though occasionally met with in Caradoc rocks, are not common as Lower Silurian forms. The most frequent are flat-branched forms allied to the living Eschara of our coasts, and which are known by the name Ptilodictya, Lonsdale (Escharopora, Hall). Pt. acuta, Foss. 30. f. 2, and Pt. dichotoma, Foss. 31. f. 5, are common species, and occur low down in the series. The more expanded forms, Pt. explanata, M'Coy, and Pt. fucoides, M'Coy, are found rather in the upper portions of the true Caradoc strata in Wales. Here, too (if not in a still higher series, or at the base of the Llandovery rocks), Fenestella subantiqua, d'Orb. (F. antiqua, Sil. Syst.), Foss. 30. f. 1, makes its appearance. There are also some other forms, both branched and encrusting, which occur in the higher Caradoc strata of Wales. Glauconome disticha, Foss. 50. f. 5, and Fenestella Milleri, f. 4, are found both in the Wenlock beds and in the Lower Silurian calcareous slates of Llansaintffraid, Glyn Ceiriog, in Denbighshire.

Of the Corals, the most prevalent are certain species of the genera Halysites, Heliolites, Favosites, and Petraia.

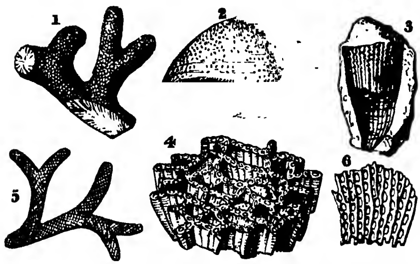
One of the most striking of these bodies, which ranges into and abounds in the Upper Silurian, and is widely spread through various countries, is the Haly-

* This curious fossil belongs truly to the Llandovery rocks, and will be noticed when their fossils are described. It is doubtfully referred the Polyzoa. It is not a Coral.

sites catenularius of Linnæus, Foss. 31. f. 4, the well-known 'Chain-coral' (Catenipora escharoides of the 'Silurian System'). Another, still more abundant in the lower rocks, is Favosites fibrosus, both branched, f. 1, and hemispherical, f. 2. Petraia subduplicata, f. 3, is but rarely found below the horizon of the Llandovery rocks; P. rugosa, Phill., and P. æquisulcata, M'Coy, are, however, not unfrequent Caradoc species.

Others, less common, are Stromatopora striatella (doubtfully grouped with Corals), Chap. X. Foss. 52; Heliolites interstinctus, p. 120, Foss. 19; H. inor-

FOSSILS (31). LOWER SILURIAN ZOOPHYTES AND POLYZOA.



1. Alveolites (Stenopora, Sil. Syst.) fibrosus, Goldfuss.
2. The same species, variety Lycoperdon, Hall.
3. Petraia subduplicata, M'Coy; rarely found in the Caradoc strata.
4. Halysites catenularius, Linné.
5. Ptilodictya dichotoma, Portlock.
6. Retepora Hisingeri, M'Coy; Caradoc rocks of Westmoreland.

dinatus, Foss. 30. f. 5; H. megastoma, f. 7. Both these last are plentiful at Robeston Wathen in Pembrokeshire. Heliolites petaliformis, p. 120, Foss. 19. f. 2, and H. tubulatus, ib. f. 1, have also been quoted by M'Coy from the Caradoc rocks of Westmoreland: H. favosus of the same author is a rare Lower Silurian species from Ayrshire. We have also Favosites Gotlandicus, Foss. 30. f. 6; F. alveolaris, p. 119, Foss. 18. f. 4; and the Sarcinula (or Syringophyllum) organum, Linn., Foss. 30. f. 4, found in the slates of Westmoreland and in the Upper Silurian limestone of Gothland in Sweden. Nebulipora of Professor M'Coy contains one or two species of minute-celled Corals, resembling Favosites, and is chiefly Lower Silurian. One, Nebulipora favulosa of Phillips, figured in the woodcut, p. 51, Foss. 11. f. 22, is very common in the Llandeilo flags; both it and Monticulipora (Nebulipora) lens, M'Coy, are very characteristic Caradoc fossils, p. 68: M. papillata, M'Coy, is both a Lower and an Upper Silurian species.

The reader has before him in these woodcuts a few only of the Corals which most frequently occur in Lower Silurian strata; but if he wishes to study many other forms of these fossils, particularly those in the Upper Silurian rocks, where Corals are much more abundant, he must consult the clear and faithful descriptions of them given by Mr. Lonsdale in the 'Silurian System,' in which work 62 species are accurately figured *. By reference to the authority of that valued friend, who assisted me so materially in preparing my original volumes, and to the works cited in the footnote, it will be seen that, of the seventeen or eighteen species here mentioned as found in the Lower Silurian, no less than eight, including the Chain-coral (Halysites catenularius), Favosites alveolaris, F. Gotlandicus, and the

* The palæontologist will also naturally consult the writings of Milne-Edwards and Jules Haime, Archives du Muséum d'Histoire Naturelle, vol. v., who have shown that several of the Corals which were supposed to be common to the Silurian and Devonian systems are not identical. See their Monograph in the publications of the Palæontographical Society, 1854. I must also specially refer the naturalist to Dana's magnificent work on Zoophytes, published as part of the results of the United States Exploring Expedition; and to Prof. M'Coy's descriptions and figures in Professor Sedgwick's work, Descript. Brit. Pal. Foss. of the Woodwardian Museum.

species of Heliolites, together with the doubtful Stromatopora striatella, are still more abundant in the upper division of the system.

Of Crinoids, or the lily-shaped tenants of the deep, most of which were attached by their root or base to submarine rocks, the inferior strata of the Silurian epoch have in general afforded fragments only. Referring the reader therefore to the Plates XIII.–XV. of this work, as containing the forms best known in the Silurian rocks when my work was published, it is enough now to state that, for the most part, broken portions of the stems only of Encrinites have been detected in the earlier portion of these deposits in Britain.

One brilliant exception, however, is the Glyptocrinus basalis, M'Coy, a Crinoid found in the Lower Silurian slates of North Wales: fine specimens of it are to be seen in the Museum of Practical Geology in Jermyn Street, and in the Woodwardian Museum at Cambridge. One or two species have been met with in the Llandeilo Flags of Shelve, Shropshire.

FOSSILS (32).

Glyptocrinus basalis, M'Coy. A Lower Silurian crinoid.

Next in order come those remarkable animals whose globular forms and strong external plates have enabled them to resist destruction better than the delicately constructed and slender-stemmed Encrinites: these are the Sphæronites of old authors; they are the Cystidea of Von Buch. Abounding in the Lower Silurian of Scandinavia and Russia, they were long ago described by Linnæus and Gyllenberg, whilst they have had much new light thrown on their natural affinities by Von Buch, Volborth, the Duc de Leuchtenberg, Edward Forbes, F. Roemer, J. Hall, J. Rofe, and others. They constituted, in the primeval era, the representatives of the Sea-urchins or Echinidæ of the Secondary and Tertiary periods and of the present day. They have affinity with Crinoids on the one hand (some possessing very perfectly formed arms and tentacles) and with Sea-urchins on the other *, and have been divided into genera called Echinosphærites, Caryocystites, Sycocystites, Hemicosmites, Cryptocrinites, &c., some of which are here figured †.

They usually occur in clusters, on the shaly surface of beds of limestone, resembling bunches of enormous grapes; and in Sweden and Russia, where thus developed, they are associated with Orthidæ and other Shells of the Lower Silurian rocks. In Britain they had not been found when the Silurian classification was first published; but by the researches of the Government Surveyors they have been detected, and somewhat plentifully, in strata first described by me as Llandeilo Flags, at Sholeshook, Pembrokeshire, but now known to belong to the Caradoc rocks (p. 74). Indeed in Britain they are not observed to occur lower down in the series ‡, although in Bohemia some species are found in rocks of the age of the Lingula-flags.

The usual forms in our country are species of Echinosphærites and Caryocys-

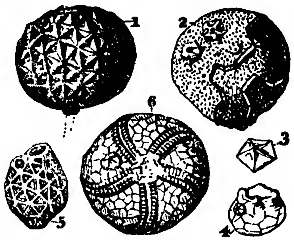
* The views expressed in the text are those of Edward Forbes. The Cystidea, at least several of them, have a close affinity with the Pentremites of the Mountain-limestone.

† Other forms of these Cystidea are given in the work, 'Russia and the Ural Mountains,' vol. ii. See also Von Buch, 'über Cystideen,' Trans. Berlin. Acad. 1845; Volborth, 'über die Echino-Encrinen,' Bull. Sc. Acad. St. Pétersbourg, t. x., and Bull. Phys. Math., ib. t. iii. No. 6; Beschr. Thier. Silur. Kalk. v. Max. Herz. v. Leuchtenberg, St. Petersb. 1843; and E. Forbes, Mem. Geol. Surv. 1848, vol. ii. pl. 2.

‡ Remains of Cystidea are now said to occur in the 'Primordial zone' of St. David's, Pembrokeshire.

tites. Echinosphærites aurantium, the commonest species in the north of Europe, is rare in Britain; but E. Balticus, Foss. 33. f. 1, and E. (Caryocystites) granatus, f. 5, both of them frequent in the Lower Silurian of Scandinavia, are found profusely in my old fossil-bearing locality of Sholeshook in Pembrokeshire; and thus our British Silurians are well paralleled and co-related with their foreign analogues. Echinosphærites arachnoideus, Forbes, occurs with them, and Sphæronites Litchi, Forbes, a globular species having pores arranged in pairs, and five protuberances round the mouth. Sphæronites punctatus, Foss. 33. f. 2, and Sph. munitus, f. 4, are common species at Bala; and a fine species of Pleu-

FOSSILS (33). LOWER SILURIAN CYSTIDEANS.



1. Echinosphærites Balticus, Eichwald. 2. Sphæronites punctatus, Forbes. 3. Ovarian pyramid of Echinosphærites granulatus, M'Coy. 4. Sphæronites (Caryocystites) munitus, Forbes. 5. Sph. (Echinosphærites) granatus, Wahl. 6. Agelacrinites Buchianus, Forbes.

rocystites, a genus which has the two halves of the cup differently constructed, has been found in the Lower Silurian shales near Llandovery. One exceedingly rare and curious form, belonging to a different group from the others, and more resembling the Silurian genus Pseudocrinites in its structure, possesses arms, which are affixed like the spokes of a wheel on the upper surface. It has been found in North Wales, and is figured in the Memoirs of the Geological Survey; it is represented above, Foss. 33. f. 6. Professor E. Forbes named this form Agelacrinites Buchianus, in honour of that great geologist the late Leopold von Buch.

Of Starfishes two species were discovered in 1844, by Professor Sedgwick and Mr. Salter, at Bala. One of these, Foss. 34. f. 1, described by the late Edward Forbes*, was thought by him to belong to the modern genus Uraster, so common on our own shores; it appears, however, to be distinct, and has been named Palæaster†; the other was unfortunately lost when it had been ascertained to belong to the true Ophiuroid group, and named provisionally Ophiura Salteri, by Professor Sedgwick. It is probably a Protaster (see p. 127, & Chap. X.).

FOSSILS (34). LOWER SILURIAN STARFISHES.

1 2

1. Palæaster obtusus, Forbes. From Bala and Waterford.

2. Palæaster asperrimus, Salter. From near Welshpool.

Palæaster obtusus has since been obtained from the slates of Wales and Ireland, and is represented in the preceding woodcut, together with a very distinct species from near Welshpool—P. asperrimus.

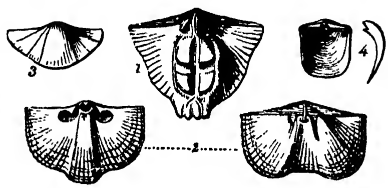
Among the Shells of the mass of the Lower Silurian strata, above the lowest or 'primordial' zone, Lingulæ again occur, though of different species. Lingula attenuata, F.. V. f. 16, is indeed one of the most characteristic shells of the Llan-

* Memoirs Geol. Survey, Decade 1.
† Ann. & Mag. Nat. Hist. for Nov. 1857; Rep. Brit. Assoc. 1856, Trans. Sect. p. 76.

ferred to the genus Strophomena) extends upwards throughout the whole series, from the oldest Llandeilo beds to the Upper Ludlow rock.

Of the two species of Leptæna which are prevalent in the lower division, the most frequent is L. sericea, Pl. V. f. 14, and Foss. 36. f. 6, which, occurring in swarms among the slates of Snowdon, is also most abundant and characteristic in the Caradoc Sandstone of Shropshire; whilst L. transversalis, Pl. XX. f. 17, published originally as a fossil of the Wenlock Shale, is now also found in the Caradoc formation of Wales and Westmoreland. The former of the two last-mentioned species has indeed a universal range, being known in Russia, Scandinavia, Central Germany, the British Isles, and America. Leptæna tenuicincta, Foss. 37. f. 4, and L. quinquecostata, f. 3, are not unfrequent Caradoc species both in England and Ireland: the latter is found deep down in the Llandeilo flags.

FOSSILS (37). LOWER SILURIAN BRACHIOPODS.

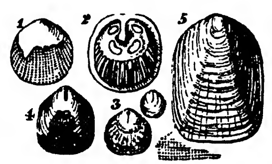


1. Orthis biforata, Schlotheim (internal cast). 2. Orthis spiriferoides, M'Coy. 3. Leptæna quinquecostata, M'Coy. 4. Leptæna tenuicincta, M'Coy; and a lateral view of the same.

The Orbiculoid and Cranioid groups, though not common in the lower division, yet afford some characteristic species. The remarkable Crania divaricata, Foss. 38. f. 2, like its congener the Crania antiquissima (Pander) of Russia, is a Lower Silurian species. Discina (Trematis) punctata of the Caradoc Sandstone, Foss. 38. f. 1, can with difficulty be distinguished from the beautiful Discina (Trematis) cancellata, Sow., of the Trenton limestone, America; and Siphonotreta micula, f. 3, a small species of a genus which is abundant in the Lower Silurian beds of Russia, is found plentifully in the trilobite-flags of Builth *.

Lingulæ, on the other hand, offer some prevailing forms. Such is L. attenuata, the characteristic Llandeilo fossil before alluded to, in p. 50. Its associates

FOSSILS (38). LOWER SILURIAN BRACHIOPODS.



1. Trematis punctata, Sow. 2. Crania divaricata, M'Coy. 3. Siphonotreta micula, M'Coy; young and full grown, natural size. 4. Lingula granulata, Phill. 5. L. tenuigranulata, M'Coy; one of the largest fossil species of Lingula known in Britain; with a portion nat. size.

are L. granulata, Foss. 38. f. 4, and a number of unpublished species. L. ovata, M'Coy, and L. tenuigranulata, f. 5, here figured, are conspicuous Caradoc species. Obolus, a genus closely allied to Lingula, is common in Russia, and,

* As an example of the confusion which might be introduced by substituting the word Cambrian for Lower Silurian, it may be mentioned that this species of Brachiopod, though collected in my oldest and best-known Lower Silurian locality of Llandeilo flags at Builth, has been published as a Cambrian fossil in the Second Fasciculus of the Palæozoic Fossils of the Cambridge Museum. The reader must, indeed, be told that very many of the fossils to which the words 'Bala' and 'Cambrian' are prefixed in that work descriptive of the Cambridge Museum, and published in 1851–53, have been alone found in my original Llandeilo and Caradoc rocks, the organic remains of which were published by me between the years 1833 and 1839. Such are:—all those fossils from the Carmarthenshire localities of Llandeilo, Mandinam, Goleugoed, Llangadoc, Noeth Grüg; all the Brecknock and Radnorshire localities, near Builth and Llandrindod; the Montgomeryshire localities, near Welshpool and Meifod, and at Allt-yr-Anker; Caradoc fossils from the West of Shropshire, &c.

though not found in our Lower, is now known to be present in our Upper Silurian *.

The primeval forms allied to the genus Terebratula are now mostly referred to the genus Rhynchonella † of Fischer. This genus is very much less frequent in the lower than in the upper division of the system. Some few forms, described in the 'Silurian System,' chiefly belong to the Llandovery rocks, and will be noticed under that head. One or two plaited species are known to occur in the Caradoc beds of Snowdon, and in the rocks near St. David's, Pembrokeshire, some of which are of Llandeilo age. Similar species, too, are found in Tyrone, and have been described by Portlock. A few smooth species, like Rhynchonella navicula, Pl. XXII. f. 12, but not identical with it, are found in the Bala Limestone. Rh. (Athyris ?) depressa, Pl. XXII. f. 17, and Rh. rotunda, f. 18, originally described from the Upper Silurian, are said by Prof. M'Coy to occur in true Lower Silurian strata.

The genus Atrypa, so often quoted in palæontological works, is now restricted, and includes only those shells which have calcareous spires inside, and beneath the beak or umbone a small area pierced by a round foramen. Thus limited, it contains only a few species; and these are most abundant in all the Upper Silurian strata, and in the Llandovery rocks. Atrypa marginalis of Dalman is the only one known with certainty to occur in the Caradoc Sandstone; and it is found in many localities in Wales and Ireland.

Of the next great class, the Lamellibranchiata, or ordinary Bivalve Shells, a few only had been discovered in the lower group of strata when my large work was published. They are now, however, ascertained to be far from rare in the more arenaceous parts of the Caradoc strata in England; and they also occur in rocks of the same age in America. The genus Pterinea (Avicula, Sil. Syst.), so common, as will hereafter appear, in the upper division, has some representatives in the lower. Pt. pleuroptera, Conrad, and Pt. tenuistriata, M'Coy (Chap. X. p. 228, Foss. 60. f. 5), are two species of this formation, quoted by M'Coy as ranging upwards to the Ludlow rock. It is probable that some other species of the genus have an equal range.

There appear to be some species of true Aviculæ; and there are several examples of that section (or rather of that distinct genus, Ambonychia, Hall) which has both valves gibbous and the anterior ear almost obsolete. These shells have been sometimes called Inoceramus, but have no affinity with that group. Ambonychia Triton, Foss. 39. f. 8, for example, is found at Llandeilo; and Portlock describes Amb. transversa and Amb. trigona from the rich deposits of Tyrone.

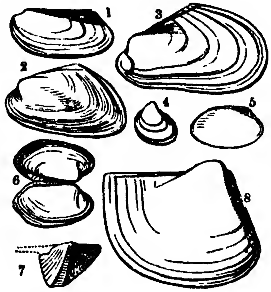
Modiolopsis, Hall, is a still more common genus in the Lower Silurian. M. orbicularis, Pl. VII. f. 1, one of the few species published in my former work, is at present known only in the Caradoc Sandstone of Shropshire; it was formerly described as an Avicula. M. modiolaris, Foss. 39. f. 3, and M. postlineata, f. 1, are frequent in the Caradoc rocks of North Wales, where M. inflata, M'Coy, and some others are also occasionally met with. M. expansa, f. 2, is a flattish species found in strata of the same age in Ireland; and several large and rounded forms occur with it. The genus is closely allied to the common Modiola, or Mussel, of our coasts.

Nucula-like shells with toothed hinges are not scarce; but few of them have been yet described. It is well, however, to note that the small triangular spe-

* Davidson's Monograph of the Brachiopoda, Palæont. Soc. 1854, p. 136.
† Some also fall into the genus Atrypa.

cies, Ctenodonta varicosa, Foss. 39. f. 4, and Ct. obliqua, f. 6, are frequent in the lower division,—the former in Wales, the latter in North Ireland. It is most probable that these are all referable to Nucula-like shells (Ctenodonta [Tellinomya, Hall], Rep. Brit. Assoc. 1851, Trans. Sect. p. 63) which, like the Isoarca

FOSSILS (39). LAMELLIBRANCHIATA.



1. Modiolopsis postlineata, M'Coy. 2. M. expansa, Portlock. 3. M. modiolaris, Conrad. 4. Ctenodonta varicosa, Salter. 5. Lyrodesma plana, Conrad. 6. Ctenodonta obliqua, Portlock. 7. Pleurorhynchus dipterus, Salter. 8. Ambonychia Triton, Salter.

of Münster, have the ligament external. Lyrodesma plana, Foss. 39. f. 5, which belongs to the same group of shells, is found in the limestone at Bala.

Orthonota (Cypricardia of the Sil. Syst.) is a genus more frequently met with in Upper Silurian rocks; but some of its species are Lower Silurian. O. nasuta occurs in the Caradoc of Horderley, and is represented in the woodcut, Foss. 13. f. 12 (p. 68). Cardiola is rare, but not wholly absent. In the preceding illustration (Foss. 39), a rare fossil is figured, Pleurorhynchus dipterus, f. 7, which, though unknown in England and Wales, has been found by Mr. J. Carrick Moore in the Lower Silurian rocks of Ayrshire, and by the Government Geologists at the Chair of Kildare, in Ireland. To these may be added a remarkable genus found in Montgomeryshire, the Megalomus of Hall. It is a thick and clumsy shell, something like the Megalodon of the Devonian rocks, but with less defined teeth. Hall's species is from the Clinton group (Llandovery rocks); the British one is from the true Lower Silurian at Horderley.

The Gasteropods, or Univalves, are now declared by naturalists to belong mainly to genera which are extinct. Such is the Murchisonia of d'Archiac and de Verneuil, formerly included in the genus Pleurotomaria. Such also are Holopea and Raphistoma of the American palæontologists, Loxonema and Macrocheilus of Phillips, and Euomphalus; and the few species of Turritella formerly quoted belong to a different genus, the Holopella of M'Coy.

It is important to remark that certain shells which abound in the younger Secondary and the Tertiary deposits, and at the present day, viz. true species of Nerita, Pleurotoma, and Buccinum, have not yet been found in these ancient rocks *. Some few recent genera of Gasteropods, however, may still be quoted,

* The reader may be surprised to find numerous species of the three last-mentioned genera spoken of in the original 'Silurian System;' but it is only of late years that the distinctions have been drawn by which such genera have been excluded from the Silurian rocks, and the accuracy of the exclusion is now agreed upon by most naturalists, although these shells have much the external appearance of the above-mentioned genera. Euomphalus is probably a very near ally of the modern genera Delphinula and Skenia: it occasionally preserves its operculum and even the nacreous lustre of its interior. These changes, made by palæontologists in the generic names, have an important bearing on the philosophy of the science, as the determination of the correct affinities of these fossils may lead us to understand the conditions under which they lived,—it having been shown conclusively, by the late Ed. Forbes, that certain conditions of depth and of sea-bottom were essential to the presence of one group of animals, while another assemblage might be indifferent to them. See also Dr. Bigsby's Tables, Quart. Journ. Geol. Soc. vol. xv. pp. 259 &c.

such as Trochus, Turbo, Natica (or Pileopsis), and Patella. Of the latter genus an Irish species (P. Saturni, Goldfuss ?) is here figured, Foss. 40. f. 9.

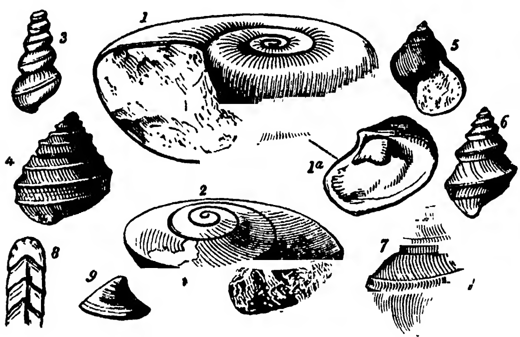
The families which appear to have existed during the Lower Silurian time were—Littorinidæ, Pyramidellidæ (in abundance), with Haliotidæ, and a rare Patella.

In the Upper Silurian are true Turbinidæ (Euomphalus), with Calyptræidæ (Pileopsis and some allied genera). The Naticidæ seem represented by one species, N. parva, Sow.; they are not common until the Devonian period.

Among the old Gasteropods, the genus Euomphalus occurs, four or five species being known in the inferior strata (one is figured in Pl. VII.). We find that Euomphalus, like many other genera, pervades the whole Silurian system; but it is far less characteristic of the Lower than of the Upper Silurian. It is not certain that any one species extends upwards from the Llandeilo Flags into Wenlock strata.

One of the most characteristic univalves of this age is the Murchisonia, more complete forms of which are given, in the annexed woodcut (Foss. 40. f. 6, 7)

FOSSILS (40). LOWER SILURIAN GASTEROPODA.



1. Maclurea Logani (?) Salter; from the Lower Silurian of Ayrshire. Operculum of M. Logani, from Canada, f. 1 *a*. 2. Raphistoma æqualis, Salter. 3. Murchisonia obscura, Portl. 4. Cyclonema rupestris, Eich. 5. Holopea concinna, M'C. 6. Murchisonia gyrogonia, M'Coy. 7. M. subrotundata, Portl. 8. Helminthochiton Griffithii, Salter. 9. Patella Saturni, Goldfuss ?

than any figured in my larger work, where they are called Pleurotomariæ. In Portlock's 'Report' several species of this genus are described from the Lower Silurian rocks of Tyrone: one of these, M. turrita, Portl., is very elegantly sculptured; another, M. subrotundata, Foss. 40. f. 7, is conspicuous for its broad rough band. M. gyrogonia, f. 6, and M. simplex, M'Coy, are common in Wales, and there are many other similar species. Turritella is absent; the Lower Silurian shells resembling it are either smooth forms of Murchisonia, such as M. obscura, Foss. 40. f. 3, in which case they show the characteristic band, or they belong to the genus Holopella, in which the striæ of growth run straight across the whorls, and are not bent into a notched or angular form. Several of the latter genus have been described from the Llandovery rocks, but they are comparatively rare in the Caradoc or the Llandeilo beds. They have in general an elongated and beaded shape, resembling the above-quoted Murchisonia obscura, Portl. 'Trochus lenticularis' of the 'Sil. Syst.' pl. x. f. 2, and several similar discoid and angular univalves, are now referred to the genus Raphistoma, Hall. This genus is exceedingly common in the Lower Silurian rocks of America; it also occurs in Scandinavia and Russia. R. æqualis, Salter *, found at Llandeilo, is here given, Foss. 40. f. 2; and others are known in the Silurian rocks of the south of Scotland and in Tyrone.

* Mem. Geol. Surv. vol. iii. p. 271.

Holopea, Hall, though rather an obscure genus of smooth rounded univalves, includes many Lower Silurian species. One is figured in Pl. VII. f. 4, as H. striatella (Littorina, Sil. Syst.); another, H. concinna, is represented here, Foss. 40. f. 5.

Other shells formerly called Turbo, *e. g.* T. rupestris, Eichw., Foss. 40. f. 4, and T. sulcifer, Eichw., T. crebristria, M'Coy, &c., belong to an extinct genus (Cyclonema of Hall) allied to Holopea. Cyclonema rupestris occurs in the Lower Silurian limestones of Ireland, and often still retains the coloured bands that decorated the shell when alive *. This feature will be dwelt upon in the concluding Chapter, as possibly limiting the depth of water at which such shells lived.

Though not yet detected in England or Wales, Maclurea (Hall), a characteristic genus of the Lower Silurian rocks of North America, has been found in strata of the same age in Scotland. The shell (Foss. 40. f. 1) appears to be sinistral or reversed, the top flattish, and the base umbilicate. In all probability, however, it should be viewed the other way upwards, and so appear with a sunken or concealed spire. Its mouth is closed by a remarkable operculum, of which f. 1 *a* shows the inner side. I collected a species of this genus in the Lower Silurian strata of Ayrshire, associated with Orthides, Trilobites of the genus Asaphus, and other Lower Silurian fossils. A Canadian species, approaching to M. magna of the United States of North America, and named by Mr. Salter, after the able geologist who discovered it in Canada, Maclurea Logani, is the form to which our British fossil is most allied. The operculum figured (Foss. 40. f. 1 *a*) is from that species. Another species, M. Peachii, Salter, has already been noticed in describing the fossil contents of the Lower Silurian rocks of the Highlands of Scotland (p. 165).

Bellerophon, a palæozoic form of the Nucleobranch Mollusks classed by some naturalists with Heteropoda, is one of those genera which specially link together the Lower and Upper Silurian divisions in one system of life. Thus B. carinatus, Pl. XXXIV. f. 8, and B. dilatatus, Foss. 41. f. 8, are common to both divisions, ranging from the Caradoc Sandstone to the Ludlow rocks in Ireland and Wales. On the other hand, there are several species which as yet are known only in the lower division, and are very characteristic of it. B. acutus (Pl. VII. f. 8), B. bilobatus (figured at page 68, Foss. 13. f. 10), and B. nodosus (f. 11) are among the common fossils of the lower part of the Caradoc Sandstone. One of these species, B. bilobatus, Sow., is equally characteristic of the same deposits in North America, Spain, and Bohemia. B. perturbatus, Foss. 41. f. 6 (Euomphalus, Sil. Syst.), is one of the common fossils of the black Llandeilo slates of Wales. There are other less-known species, and some are yet unpublished.

Certain naturalists regard the genus Bellerophon as the shell of a Cephalopodous animal, differing from the ordinary forms of that class in the want of septa or partitions within the shell. Although there is some ground for the supposition, these shells are now usually believed to be Nucleobranchiata (or Heteropoda), allied to the floating Carinaria or Glass-shell, which they much resemble both in form and sculpture.

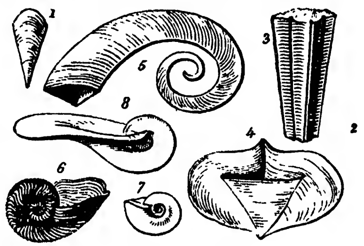
The large Irish Lower Silurian fossil, Ecculiomphalus Bucklandi, Foss. 41.

* Cyclonema rupestris, Eichw., from the Lower Silurian limestone of the Chair of Kildare, Ireland, has concentric bands of colour, and an Orthoceras of the Caradoc Sandstone exhibits very distinct longitudinal stripes. Now as Edward Forbes (Proceed. Roy. Soc. vol. vii. p. 21) has shown that coloured shells, striped or banded, do not usually descend to greater depths than from 15 to 20 fathoms, we may by this fact strengthen the inferences arrived at in Chapter XX. from other data, that some of the Silurian sea-beds, extending over considerable areas, were formed in comparatively shallow water. Mr. Gwyn Jeffreys, however, finds that coloured shells exist at greater depths; so that the conclusion must be adopted with caution.

f. 5, may probably be compared with the modern genus Atlanta—if its thin shell, triangular section, and finely striated surface do not betray affinity with the group next mentioned.

There are certain genera, now clearly ascertained to be forms of Pteropoda—one of the inferior groups of Mollusca. Of Conularia, for example, a most beautiful ornate form, there are two or three species in the Lower Silurian. C. elongata, figured in the next woodcut, Foss. 41. f. 3, is frequent in Ireland; and C. Sowerbyi, Pl. XXV. f. 10, ranges upwards from the Caradoc strata to the Ludlow rocks. M. Barrande has figured many curious and large forms of Conularia from the Silurian rocks of Bohemia, one of which is spirally curved. Theca, a genus exceedingly like the modern Clio, has two species at least in the lower division, viz. T. triangularis (Orthoceras of Portlock), Foss. 41. f. 2, and another species, f. 1 (T. triangularis of Hall), to which Mr. Salter applies the name T. reversa. It is found in North America, Scotland, and Wales, and is distinguished by having the dorsal (and not the ventral) surface convex; otherwise it is much like T. Forbesii, Sharpe.

FOSSILS (41). HETEROPOD AND PTEROPOD MOLLUSCA OF THE LOWER SILURIAN STRATA.



1. Theca reversa, Salter (dorsal view). 2. T. triangularis, Portl. (dorsal and ventral sides). 3. Conularia elongata, Portl. 4. Pterotheca transversa, Portlock. 5. Ecculiomphalus Bucklandi, Portl. 6. Bellerophon perturbatus, Sow. 7. B. acutus. 8. B. dilatatus, Sow.

Figs. 5 and 8 are species often 3 inches wide. The figures are much reduced.

Pterotheca is a genus proposed (Report Brit. Assoc. 1852) for a wide shell like Cleodora: Pt. transversa is here given, f. 4. Pt. undulata, Salter, is a large and beautiful fossil found in North Wales and Shropshire.

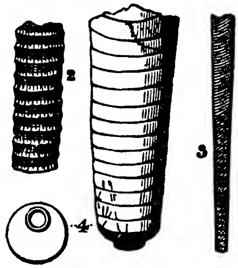
It is to be remarked that these ancient forms of their order were gigantic in comparison with their modern representatives.

Cephalopodous or chambered Shells of the genera Orthoceras, Cyrtoceras, and Lituites occur in the Lower Silurian rocks. In the original Silurian region they are, indeed, less abundant in the lower than in the upper divisions of the system; but on the continent of Europe, particularly in Scandinavia, where they occur under different conditions, and in limestone, they are more frequent in the Lower than the Upper Silurian. Among the earlier developed British species are to be noted Orthoceras politum, M'Coy, a large smooth shell seen by myself *in situ* in Ayrshire*; O. vagans, Foss. 42. f. 1; O. bilineatum, f. 2; O. tenuicinctum, f. 3: the latter is a beautiful fossil. Another species characteristic of the Lower Silurian strata, and having a large lateral siphuncle, is O. Brongniarti of Portlock, f. 4; it is supposed to be identical with one from North America, where similar forms are common in the Lower Silurian rocks. The great Orthoceras of the same strata of Scandinavia and Russia, O. vaginatum, Schlotheim, is occasionally three feet long; it has been found in Scotland†. Smooth Orthocerata, on the contrary, with slender central siphuncles, are not confined to either the upper or lower division.

* See Quart. Journ. Geol. Soc. vol. vii. pl. 10. † Ib. p. 177.

It must here be specially noted that in the progress of research no less than eight species of Orthocerata have, in England, Wales, and Ireland, been found to range from strata of the age of the Caradoc rocks to the Upper Silurian*, several of them even into the Upper Ludlow rock: *e. g.* O. angulatum, Wahl. (O. virgatum, Sil. Syst.); O. ibex, Sil. Syst.; O. subannulatum, Münst.; O.

FOSSILS (42). LOWER SILURIAN CEPHALOPODA.



1. Orthoceras vagans, Salter. 2. O. bilineatum, Hall. 3. O. tenuicinctum, Portl. 4. O. Brongniarti, Troost.

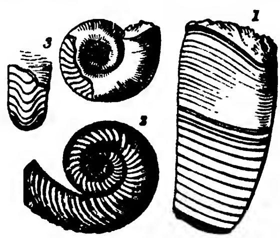
Some of the forms of Orthoceras that are most common in the Lower Silurian rocks.

annulatum, Sil. Syst. (O. undulatum of foreign authors); O. filosum, Sil. Syst.; O. subundulatum, Portl. (Creseis Sedgwicki, Forbes); O. tenuicinctum, Portl.; and O. primævum (Creseis primæva, Forbes). There are probably others which have as great a range†.

The singular Orthoceras bisiphonatum of the Sil. Syst., only found in one locality, near Llandovery in South Wales (Pl. XI. f. 5), appears to have two siphuncles, and belongs, in the opinion of Mr. Salter, to a distinct genus, for which he has proposed the name of Tretoceras‡. It will be again noticed under the Llandovery formation. Oncoceras has been already mentioned, p. 165.

There are several species of the genus Lituites in these old strata. L. cornu-arietis, Foss. 43. f. 2, and L. Hibernicus, f. 3, are good examples of our British species. The former is also found in Scandinavia. L. anguiformis, Salter, is a third; and there are other species in the Llandovery rocks. Cyrtoceras,

FOSSILS (43). LOWER SILURIAN CEPHALOPODA.



1. Cyrtoceras inæquiseptum, Portl. 2. Lituites cornu-arietis, Sow. 3. L. (Trocholites) Hibernicus, Salter.

Curved forms of Cephalopoda, rare in British Lower Silurian strata.

which is distinguished by being much less curved than Lituites, includes several species in Britain: one, C. inæquiseptum, Portl., from Ireland, is here represented, f. 1; and some others are figured by Portlock; and one of the Ayrshire Cephalopods is probably the Cyrtoceras multicameratum, Hall, of the United States.

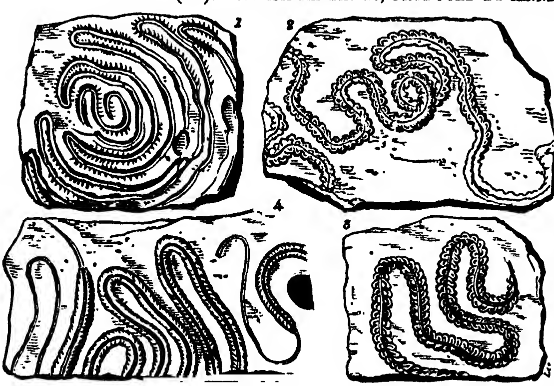
* Synopsis of the Palæozoic Fossils, by Sedgwick and M'Coy, pp. 313 &c.
† See Plates XXVI. to XXIX., and Chap. X. for some of these species.
‡ Quart. Journ. Geol. Soc. vol. xiv. p. 179.

Annelides, or Sea-worms, we have already seen, Chap. II., prevailed in some of the earliest sediments in which traces of organic remains are found *. They were not less plentiful in succeeding periods of the Silurian epoch, and occurred both in the form of burrows in the strata (Scolites), and as tracks upon the surface (Helminthites &c.). It is scarcely doubtful that some of the long sinuous tracks observable on these old sediments were made by wandering species of this tribe; but the idea has nevertheless been suggested by Geinitz, that some of those usually called Nereites may be soft and fleshy forms of Graptolithina, and therefore have no real affinity with the Annelides. Certain branched forms found in the old rocks of Thuringia, and described by Prof. Richter, give considerable force to this suggestion. Burrowing Crustacea also form such markings†.

Specimens of these tracks were figured, as previously stated, from Llampeter, in South Wales, where they occur in strata which have been shown to overlie the Llandeilo rocks (see p. 72): *e. g.*, Nereites Cambrensis, Foss. 44. f. 3; N. Sedgwicki, f. 2; and Myrianites MacLeayi, f. 1.

Another form of these creatures, Crossopodia Scotica, f. 4, is given from specimens collected by Professor Sedgwick, in the Graptolitic schists near Moffat, in Dumfriesshire, a locality which I have also examined, and where I found other species of these supposed long Sea-worms. The length of some of these creatures must have been prodigious, probably many yards, judging from the frequent parallel coils which are exhibited on the surface of the schists. (The annexed figures are very much reduced.) It should, however, be borne in mind that in many cases we see only the track of the Worm, and not the impression

FOSSILS (44). TRACK-MARKINGS, PRODUCED BY ANNELIDES &C. ‡



1. Myrianites MacLeayi, Sil. Syst. 2. Nereites Sedgwicki, ib. 3. N. Cambrensis, ib. 4 Crossopodia Scotica, M'Coy. (All much reduced in size.)

Tracks of Sea-worms, and probably of other animals, in fine muddy sediments, now altered into slates. South Scotland and Wales.

of its soft body, which could rarely be preserved. Such tracks as these are met with in all the Palæozoic rocks; but the burrows of the Worms (Scolites and Arenicolites) are yet more frequent. Wherever the sediments are sandy these creatures seem to have been present; and the markings generally attributed to Fucoids are for the most part only the filled-up burrows of marine Worms and other animals.

* See Quart. Journ. Geol. Soc. vol. xii. p. 246; & vol. xiii. p. 199.

† It is to be remembered that, according to Mr. Albany Hancock and other naturalists, such markings as these so-called Worm-tracks are in many cases caused by the burrowing of Crustaceans beneath the sandy surfaces,—the galleries thus formed falling in, and producing furrow-like markings, with or without transverse notchings or lateral marks caused by the jerking advance of the burrower. Professor Dana ('Manual of Geology') and Professor Rupert Jones ('Geologist') refer the Canadian Climactichnites to the burrowing of Trilobites; and Principal Dawson finds somewhat similar markings produced by the Limulus ('Canad. Geol. & Nat.'). See also Prof. Nicol's remarks on little borings at Durness, above, p. 166, *note*.

‡ See Sil. Syst. pp. 363, 669, &c.

The Tentaculites and Cornulites of the earlier primeval strata must also be mentioned as remains of animals of this order, being probably Worms with shelly tubes like those of Serpula, but distinguished easily by their annulated form and cellular structure * (see Pl. XVI. f. 3–10, for the form and magnified sections of C. serpularius). Tentaculites Anglicus, Pl. I. f. 3, in Britain, is a characteristic Caradoc fossil; but is also found abundantly in the Llandovery rock (T. scalaris of the Sil. Syst. is thought by some to be the interior cast of it). Cornulites serpularius is a cosmopolite of this age, ranging from Sweden to North America; but, unlike the Tentaculite just mentioned, it ascends from the Lower Silurian strata, where it is rare, to the very summit of the Ludlow rocks.

Crustaceans.—Nearly all the Articulata, besides the Annelides above mentioned, which have yet been detected in the Lower Silurian rocks belong to the extinct family of Entomostracous Crustaceans called Trilobites. The Silurian era was evidently one in which these animals flourished most; for they became infinitely less abundant in the Devonian, and expired before the close of the Carboniferous era, during the earlier part of which, as will hereafter be seen, very few of their genera prevailed or lived on. As already indicated, we find some Trilobites in the oldest accumulations in which animal remains occur †; and it is now to be remarked that whilst, on the whole, certain genera and species of these creatures are more exact indicators of the successive strata than the other classes of animals, and that several genera are absolutely peculiar to the Lower Silurian rocks, there are some species, widely diffused over the world in strata of this era, which are common to both divisions.

The researches of Messrs. Hicks and Salter in the lowest part of the 'Primordial' Silurian rocks of St. David's Head, in South Wales, have resulted in adding many new species to the fauna of this series. In the annexed diagram (Foss. 45) will be found some of the chief forms of Trilobites that occur in the lowest Lingula-flags. The occurrence of three new species of Paradoxides (P. aurora, P. Davidis, and P. Hicksii, of Salter), added to the already well-known P. Forchhammeri, Angelin, tends to link on still more strongly the Silurian fauna of these islands to that of Sweden and Norway.

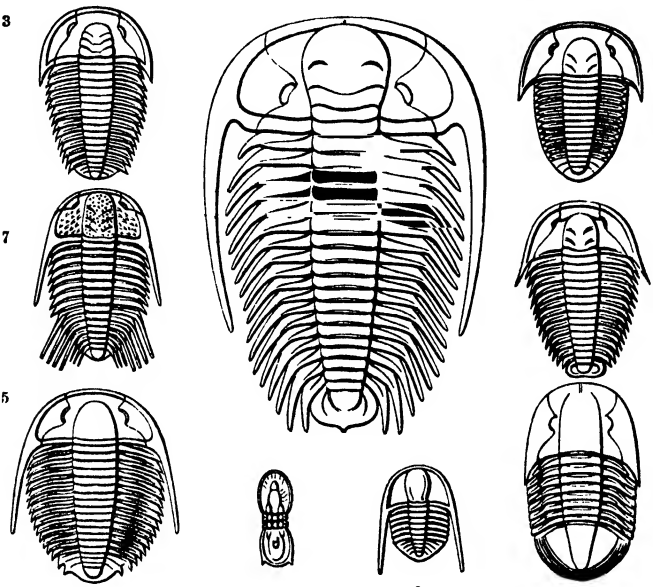
Olenus micrurus, fig. 2, and O. cataractes, fig. 3, together with Agnostus princeps, fig. 4, are all found in the black Lingula-schists of North Wales. The last, A. princeps, occurs in the Black Shales of the Malvern Hills, as well as in the Upper Lingula-flags of Penmorfa and the Tremadoc Slates of Portmadoc. Conocoryphe depressa, Salter (Ellipsocephalus? of my former edition, p. 47, Foss. 7. fig. 2), is a Lower Tremadoc Species, and may probably be found to occur in the Upper Lingula-flags when these shall have been more carefully examined. C. invita, Salter, from the Upper Lingula-flags of Penmorfa (Tremadoc), so closely resembles C. Emmerichii of Barrande that it may almost be mistaken for that

* These fossils, Tentaculites and Cornulites, have been assigned to various groups of animals, the notion that they were parts of crinoidal creatures being the most generally accepted. They were, however, shelly tubes, of a highly complex cellular structure, not jointed tentacles or stems, and could by no means be parts of such animals. —J. W. S.

† For example, in the Cambrian rocks of the Longmynd, in the Alum-slates of Sweden (Regiones A. B. of Angelin), in the Lingula-slates of North Wales, and in the Lowest Silurian of the United States. This is the zone to which M. Barrande first attached importance ('Zone primordiale') by working out its very peculiar and remarkable fauna in Bohemia.

species, were it not that the glabella has only two pairs of furrows and is long and urceolate. The British species is a good representative of Barrande's

FOSSILS (45). LOWER SILURIAN TRILOBITES OF THE 'PRIMORDIAL ZONE' OF WALES.



1. Paradoxides Davidis, Salter. 2. Olenus micrurus, Salter. 3. Olenus cataractes, Salter. 4. Agnostus princeps, Salter. 5. Angelina Sedgwickii, Salter. 6. Ampyx prænuntius, Salter. 7. Cheirurus Frederici, Salter. 8. Conocoryphe depressa, Salter. 9. Asaphus (Isotelus) Homfrayii, Salter.

Bohemian type. Angelina Sedgwickii, fig. 5, Ampyx prænuntius, fig. 6, Cheirurus Frederici, fig. 7, and Asaphus (Isotelus) Homfrayii, fig. 8, are all exclusively Upper Tremadoc species *.

The genera of Trilobites peculiar to the Lower Silurian, not only in this country, but on the Continent and in America, are:—Olenus, Conocoryphe, Agnostus, Paradoxides, Cybele, Trinucleus, Ogygia, Asaphus, Remopleurides, and the trilobed forms of Illænus, the first four being principally (though not wholly, except Paradoxides) confined to the lowest division or Lingula-flags. On the other hand, the genera Ampyx, Calymene, Lichas, Proetus, Homalonotus, Cheirurus, Encrinurus, Bronteus, and that division of Illænus which I still believe to be a true genus † (Bumastus, Murch.), are found both in the Lower and Upper Silurian. Mr. Salter has reminded me, further, that there is scarcely one genus of the upper division which had not previously existed in the earlier period.

Of these there is perhaps no one species which has a greater vertical range,

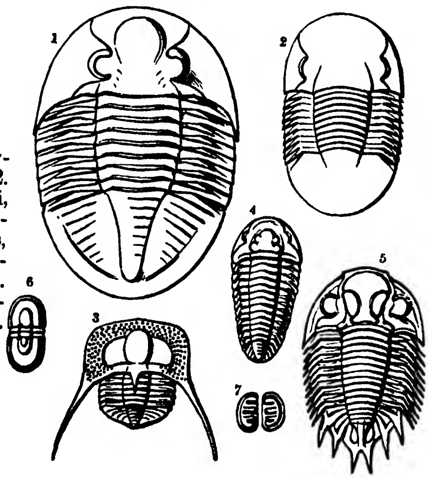
* The reader who wishes to study these and other Trilobites must take in hand Mr. Salter's masterly 'Monograph of the British Trilobites,' now in course of publication by the Palæontographical Society.

† The pygidium is simple, not trilobed as in most species of Illænus.

or is more widely diffused in geographical space, than the long-known Dudley fossil, Calymene Blumenbachii, Brongn. When this Trilobite was described in the 'Silurian System,' it was considered to be typical of the upper rocks only, whether of Wenlock or of Ludlow age; but it has since been found in abundance in the lower strata of the Caradoc formation, even near Snowdon, and I have myself procured it from beds of Caradoc Sandstone in Shropshire. Again, a variety of this species occurs in the Lower Silurian rocks of Tyrone; and thus, like many examples of the other classes of marine animals which lived in primeval days, this Crustacean links together the Lower and Upper Silurian in one system of life. (See Pl. XVIII. f. 10. The head is represented, Foss. 13. f. 1.) It has also been found in Sweden, Bohemia, North America, and Eastern Australia (?), and always in company with similar generic forms. Acidaspis Brightii, Pl. XVIII. f. 7, and Cheirurus bimucronatus, Pl. XIX. f. 11, also occur in both divisions,—the former, however, but rarely, the latter abundantly. So do also Cyphaspis megalops, M'Coy, and Staurocephalus Murchisoni, Barr., a small Trilobite with a globular head and serrate tail. The Lower Silurian fossil, Pl. II. f. 3, 4, called Asaphus Vulcani in the 'Silurian System,' is a species of Homalonotus, a genus formerly thought to be peculiar to the Upper Silurian, but of which several examples are now known in the lower division.

FOSSILS (46). TRILOBITES, &c., TYPICAL OF LOWER SILURIAN ROCKS.

1. Asaphus Powisii, Murch. 2. Illænus Davisii, Salter. 3. Trinucleus concentricus, Eaton (Trin. Caractaci, Sil. Syst.). 4. Calymene brevicapitata, Portlock.



5. Lichas laxatus, M'Coy. 6. Agnostus trinodus, Salter. 7. Beyrichia complicata, Salter, enlarged. (The last is not a Trilobite, but a Bivalved Phyllopodous Crustacean.)

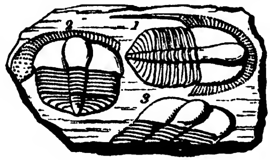
The principal forms which have proved unerring indices of the Lower Silurian of Britain are Paradoxides, Olenus, Agnostus, Conocoryphe, Dikelocephalus, and the true Asaphus (such as A. Powisii, Foss. 46. f. 1; A. tyrannus, Pl. I. f. 4, 5, and Pl. II. f. 1), with five species of Trinucleus, Pl. IV., all of which were formerly published as true Lower Silurian types.

Trinucleus concentricus (Caractaci, Sil. Syst.), Pl. IV. f. 2–5, Foss. 46. f. 3, and Foss. 47, has a very extensive Lower Silurian range both in Europe and America. This species varies greatly in form and markings; and, being a very common species, it is met with in every variety of distortion and compression, so that it might often at first sight be referred to a number of different species.

Trinucleus Murchisonii, Foss. 9. f. 7, together with the remarkable species T. Gibbsii, Foss. 10. f. 7, have already been quoted from the lowest beds (pp. 48, 51). T. fimbriatus, Pl. IV. f. 7, and T. Lloydii, f. 6, are good indications of the Llandeilo flags, for they occur in them only; while T. seticornis, Hisinger, a species found in Wales, Scotland, Ireland, and also in Sweden, is, on the contrary, exclusively a Caradoc form (see p. 69.)

FOSSILS (47).

TRINUCLEUS CONCENTRICUS: THREE SPECIMENS, DISTORTED BY SLATY CLEAVAGE.



This woodcut, in illustration of the various forms which a single species may assume under the influence of that change in the strata which is called slaty cleavage (see p. 32), represents a group of forms, apparently very dissimilar, but all of the same species, here given in their natural position on a fragment of slate. (Phillips, Report Brit. Assoc. vol. xii. pp. 60, 61.)

Better specimens of some species of Trilobites having been found than those which were collected at the time of the publication of the 'Silurian System,' figures of them are given in the following woodcut, Foss. 48, namely Phacops conophthalmus, f. 3, and Ampyx (formerly Trinucleus) nudus, f. 7. Several species, not there described, have been since added to our lists, and a few of them are also here figured. Cybele verrucosa, f. 2, is one of these, and is a common species in Britain and Sweden. C. rugosa, Portlock, Encrinurus baccatus of the same author, E. sexcostatus, Salter, Harpes Flanagani (Foss. 48. f. 4), and H. Dorani, Portl. (the latter both in Ireland and Wales), are all Caradoc or Bala species. Remopleurides dorso-spinifer, Foss. 48. f. 5, and three other species, Acidaspis bispinosa, f. 6, Cyphoniscus socialis, f. 8, and Cheirurus clavifrons, f. 1, all figured at p. 206, are common in Pembrokeshire and Ireland; Cheirurus gelasinosus, Portlock, is now a well-known species in Scotland and North Ireland. Lichas Hibernicus, from Tyrone, and Lichas laxatus, Foss. 46. f. 5, are examples of a highly complex genus not known in a complete form when my former work was printed. Illænus Davisii, Foss. 46. f. 2, with Il. Bowmanni, Salter, from Bala, and Il. Murchisoni, Salt., from Carmarthenshire, are common Trilobites. Agnostus trinodus, Foss. 46. f. 6, is a Caradoc fossil; A. Maccoyii, Pl. III. f. 7, from Builth, is from the Llandeilo flags. A. pisiformis, Linn., the Swedish species, has been already quoted, p. 45.

Some species of Acidaspis from Shropshire, and several fine forms from the Girvan district of Ayrshire have been figured by Professor Wyville Thomson *, of Belfast, and Mr. Salter; and there are numerous species and even genera yet undescribed.

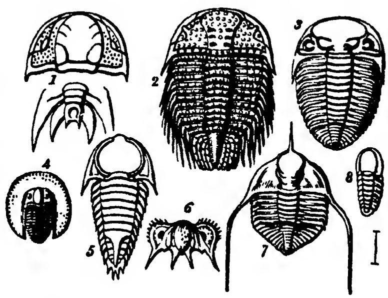
The minute Bivalved Crustacean of the Phyllopod tribe, Beyrichia complicata, Foss. 46. f. 7, occurs throughout the whole of the Lower Silurian region of Shropshire and Wales. Of this last-named genus several other forms are known: B. Barrandiana, Jones, is Lower Silurian; B. Klœdeni, M'Coy, B. siliqua, Jones †, &c., are Upper Silurian species. The allied genus Primitia has

* Quart. Journ. Geol. Soc. vol. xiii. p. 206.
† Ann. & Mag. Nat. Hist. 1855, vol. xvi. pls. 5 & 6.

also Lower Silurian forms (P. strangulata, Salter, P. simplex, Jones, &c.), and Upper Silurian (P. umbilicata, Jones, P. Roemeriana, Jones, &c.). The genus Leperditia (composed of larger, smooth-forms of this group) also furnishes some British Silurian species *; Entomis, another Phyllopod, is found both in Scotland (Pentland Hills) and Shropshire; and two or three large fossils of the Phyllopod group have also been collected in the black slates of the South of Scotland (p. 152).

No other tribes of Crustaceans than the Trilobites and the Phyllopods above noted, with the Phyllopodous Hymenocaris vermicauda, mentioned at p. 44, have been found in the Lower Silurian rocks of Britain. In the sequel it will be seen, that a group of Crustacea, vastly superior in size, but perhaps not of higher organization than those above cited, is found in the uppermost zone of the system.

FOSSILS (48). LOWER SILURIAN TRILOBITES.



1. Cheirurus clavifrons, Dalm. 2. Cybele verrucosa, Dalm. 3. Phacops conophthalmus, Beck. 4. Harpes Flanagani, Portl. 5. Remopleurides dorso-spinifer, Portl. 6. Acidaspis bispinosa, M'Coy. 7. Ampyx nudus, Mur. 8. Cyphoniscus socialis, Salter: the line beneath indicates its natural size.

With regard to the distribution of the British Trilobites, I would direct the attention of the reader to the Descriptions of the Lower Palæozoic Fossils in the Cambridge Woodwardian Museum, by Professor M'Coy, in order that he may see how many species, even in that one rich collection, are common to what have been so long and so generally called the Lower and Upper Silurian rocks.

He will see that out of fifty-six species of Trilobites there enumerated (being double the list first published in my original work) nearly all the new forms have been found in localities of Montgomery, Radnor, Brecon, Carmarthen and Pembroke, which were laid down by me as Lower Silurian on the map,—a strong indication that the region first described as Silurian still affords the best fossil types.

It is here important to remark that the numerous Footmarks in the Potsdam Sandstone or lowest Silurian rock of North America, which were at first supposed to have been made by Tortoises, were, in consequence of the discovery of better specimens, subsequently referred by Professor Owen to Crustaceans †; and tracks of a similar kind, but far smaller, have been found in our own country (see above, p. 151). Hence this last class of animals may still be considered the highest type of life in the earliest

* Jones, Ann. & Mag. Nat. Hist. 1856, vol. xvii. p. 95.

† See Quart. Journ. Geol. Soc. vol. vii. p. 247, and vol. viii. p. 223. The zeal of that acute and laborious geologist Sir William Logan, in procuring specimens and casts of a very great number of these large and curious impressions, cannot be too much commended. In default of these labours, most erroneous ideas would have been propagated respecting the Lower Silurian fauna.

fossiliferous strata known. It is, indeed, a remarkable fact that the most sedulous research in many parts of the world has failed to discover the trace of any vertebrated animal in the lower division of the Silurian system. All the marine animals (amounting to many hundred, perhaps even to a thousand species) already known belong to the invertebrated classes, no Fish having yet been observed. This observation applies also to the Upper Silurian rocks of Britain, with the exception of their highest bands,—a fact formerly dwelt upon in the 'Silurian System.'

Having thus referred to the figures first published in my original work, and now reproduced at the end of this volume, as well as to other types of Lower Silurian age which have been subsequently discovered, we now pass on to consider the assemblage of fossil animals specially characteristic of the Llandovery rocks—the formation which connects the Lower and Upper Silurian divisions.

Fossils of the Llandovery Rocks.—The principal organic remains belonging to this zone, which I previously regarded as the upper portion of the Lower Silurian rocks, are now eliminated from the catalogues through which they were diffused in the 'Silurian System' and in the first edition of this work, and are here brought together. (See Pls. VIII.-XI.; and Foss. 15, p. 90.)

This important and varied group, which is also found to intervene between the much greater masses of Lower and Upper Silurian rocks in Russia, Scandinavia, and America, is nowhere more largely developed than in the British Isles. Though linked on to the Lower Silurian by several typical forms, the fauna of these rocks has, on the whole, a peculiar facies; and many of the species in the superior division of the series are Upper Silurian. The great number of Trilobites we have been considering in the earlier part of this Chapter have disappeared, and a few rare species of those ancient Crustaceans, including one or two that are specially distinctive of this intermediate series, are mingled with others which become plentiful in the Upper Silurian rocks. The prevailing Corals, Brachiopods, and Univalves differ but little from those of the inferior strata; there being several typical Shells which continued to live on. On the other hand, certain forms which have not been found in the Llandeilo and Caradoc formations give a marked impress to this group. Some of these differences may, no doubt, be due to the gravelly and sandy nature of the strata, compared with the more argillaceous materials of the Lower Silurian rocks; but this explanation will not suffice when the arenaceous members of both groups are put in comparison.

Though Graptolites are rare, G. priodon is present, a species which ranges from the true Lower Silurian up to the Ludlow rocks. The Corals are by no means few in number; and many of them—such as the Chain-coral (Halysites), the various species of Favosites and Heliolites, Syringopora, &c.—are the same as those known in the Lower and Upper Silurian. Favosites Gotlandicus and Heliolites interstinctus are common everywhere, and these species seem to have been indifferent (as very common species usually are) to the nature of the seabottom on which they lived. Some new species are added, both of the Millepore (Zoantharia tabulata) and Cup-coral (Rugosa *) groups, which will be noticed in their proper places.

* This group of the Actinozoa will be again referred to in the sequel.

The Cup-corals chiefly belong to the genus Petraia, which is eminently characteristic of the Llandovery rocks, but comparatively rare either above or below them. The most common species is Petraia subduplicata, Foss. 15. f. 11, p. 90, which, with its elegant variety, crenulata, occurs in nearly every locality, both in the upper and lower portions of the deposit, in Wales, Scotland, and western Ireland. Petraia elongata, Phill., a larger species, is more common in the upper than in the lower beds, as at May Hill, Presteign, &c.; while P. bina, Lonsdale, Foss. 53. f. 7, is apparently confined to the upper division, and ranges into the Wenlock rocks. P. æquisulcata of M'Coy, another large species, occurs near Girvan in Scotland, and, with P. subduplicata, M'Coy, is sometimes found in true Lower Silurian rocks. A square form, named Petraia quadrata by M'Coy, is found near Galway; it belongs, however, to the genus Goniophyllum, Milne-Edwards, and is the same as the Wenlock species of Gothland, the Goniophyllum quadratum, according to that author. There are also other species, as well as some Cup-corals of a larger size, which may be species of Cyathophyllum or Omphyma; and these are chiefly in the upper strata of the formation.

The class of Polyzoa, which is not absent from the Lower Silurian rocks, as before mentioned, is represented here by several species. Though not yet clearly defined, they have been chiefly referred to branched forms of the genus Ptilodictya. Pt. dichotoma, p. 189, Foss. 31. f. 5, a Lower Silurian species, is the most frequent; but the Wenlock forms, Pt. lanceolata and Pt. scalpellum (Foss. 50. f. 6, & 51, pp. 216, 217), also occur, with several incrusting species. The most remarkable of these, if, indeed, it be allowed to remain in this group of fossils, is the Nidulites favus, p. 188, Foss. 30. f. 3. This fossil is characteristic of the Lower Llandovery series both in South Wales (Haverfordwest) and in the South of Scotland (Girvan), in each of which localities it is associated with the same fossils. It was for some time believed to be the nidus of a Gasteropod, similar to that made by the modern Natica*, the cup-like form of which it imitates. This explanation fails, however, when the fossil is more closely examined, since the cells are equal and regular on both sides of a central lamina and are set back to back like the cells of a honeycomb—whence the name. At the bottom of the cells a minute pit or depression is frequently visible, and this becomes a tubercle on the cast (in which state the fossils are always found). No trace of any upper plate or cover to the cells (which would exist in all the analogous types of Polyzoa) has been detected. The cells would seem to have been quite open at the top; and as they are much larger than in any living species of that group, the exact affinity of the fossil has yet to be determined: possibly it belongs to the Amorphozoa.

Fragments and stems of Encrinites are not uncommon; but no perfect specimens have yet been obtained—although throughout the conglomerates and sandstones of this age in South Wales Encrinite stems are the chief, and often the only fossils. These stems are usually hollow, a character common to all the Lower Silurian species; while those of the Upper Silurian are mostly compact, with a small perforation only. The Llandovery rocks contain, however, both these kinds. A large species of Encrinite, with tuberculate joints alternating with very narrow plain joints, is found everywhere in the Upper Llandovery strata, and is figured from Presteign, where it abounds (Pl. X. f. 1).

Cystidea are very rare, a few detached plates occurring here and there in South Wales; the curious genus Pleurocystites (p. 191), however, is found at

* See Quart. Journ. Geol. Soc. vol. vii. p. 174.

the base of the series near Llandovery. The same species, Pl. Rugeri, Salter *, also occurs in the immediately underlying Caradoc formation. When this family of Echinoderms appears in Upper Silurian strata, the species (and, indeed, most of the genera) are quite distinct from those of the Lower Silurian rocks.

The Brachiopods are, as throughout the Silurian system, the most abundant fossils; and, as might be expected, the species which range from the lower to the upper division are the most common. The genera Orthis, Leptæna, and Strophomena are still prevalent, and many of these are the same species which have been quoted as Lower Silurian types. Discina is seldom met with. Rhynchonella, Atrypa, and Spirifer, which are rare in Lower Silurian rocks, become plentiful.

The Pentameri (including Stricklandiniæ) are, however, the characteristic fossils which impart to this zone its peculiar and distinct facies. No less than five species, whether smooth or only slightly ribbed, occur; and of these, P. lens, Sow., and P. oblongus, Sow., are the best-known and the most widely spread. The typical species, P. oblongus, is easily distinguished from the others, P. lens and P. liratus, Sow., by the great length of the mesial septum, which in these latter is quite a short appendage to the V-shaped chamber *. The two longitudinal plates, also, which divide the upper valve, are peculiar to this species; whilst in P. lens they are very short, and in P. liratus are reduced to a pair of processes which pass inwards, but do not show upon the surface of the cast (see Foss. 15. f. 1 & 3, p. 90); these last two species are referred by Mr. Billings to his new genus Stricklandinia Pentamerus globosus, Sow., is a rare species, easily recognized by its globular shape; and P. undatus, Sow., is small and broad, with a wide central fold, and very short dividing plates. (See Plate VIII.)

The distribution of these species is as follows:—In the Lower Llandovery rocks of South Wales, P. undatus, Sow., and P. (Stricklandinia) lens, Sow., are everywhere found,—P. globosus, Sow., and P. oblongus, Sow., being rare. In the upper series, whether in South Wales, Shropshire, or in the South of Scotland (as at Saugh Hill near Girvan), P. oblongus is the prevailing fossil, occurring often in great banks to the exclusion of all other fossils, but generally accompanied by the species just named. At May Hill and the Malverns, Stricklandinia lens is by far the more common species; St. lirata accompanies both these in the higher beds, and is the only one of the five species which ranges into the base of the Wenlock formation.

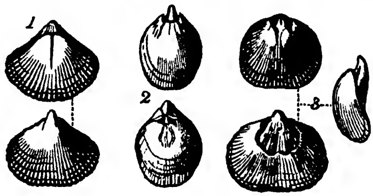
Of Terebratuloid shells, two or three are typical of the formation. The characteristic species of the Lower Llandovery rocks is the smooth shell Meristella angustifrons, M'Coy, Foss. 49. f. 2. It was first described from the sandstones of Mulloch, Ayrshire, and has since been detected near Builth, and in the lower beds at Llandovery. Meristella crassa, Sow., Pl. II. f. 7, is one of the commonest species in the same beds, and apparently confined to them. M. furcata, Sow., Pl. IX. f. 12, one of the same group, is an Upper Llandovery species. Rhynchonella decemplicata, Sow., f. 15, is a characteristic shell of the Upper Llandovery rocks, and abounds through the Malvern and May Hill districts, and round the flanks of the Longmynd. It is never found in the Lower Llandovery beds, but occurs in the Denbighshire sandstones, associated with Upper Silurian

* Mem. Geol. Surv. vol. iii. p. 288.

† Pentamerus undatus, a most abundant species, is considered by M'Coy to be identical with P. linguifer of the Woolhope and Wenlock limestones. The great point, however, on which I relied in formerly classing these rocks as Lower Silurian, was the invariable absence of their type shell P. oblongus, and its usual associates, from all the true Upper Silurian rocks. For a description of the structure of Pentamerus, consult Mr. Davidson's Monograph, Palæontographical Society, vol. i. p. 97; and for excellent descriptions of the species, see Prof. M'Coy in the Synopsis of the Woodwardian Museum. The P. microcamerus of this author appears not to be distinct from P. lens.

fossils only. Rh. nucula, Sow., Pl. XXII. f. 1, occurs with it at Tortworth and May Hill. Another species, which cannot be distinguished from Rh. obtusiplicata of Hall, is found in the conglomerates on the west flank of the Worcester Beacon,

FOSSILS (49). SOME LLANDOVERY BRACHIOPODS.



1. Rhynchonella? (like Rh. serrata, M'Coy). 2. Meristella angustifrons, M'Coy. 3. Orthis reversa, Salter. (All occur in the South of Scotland and the West of Ireland.)

Malvern. Rh. serrata (?), M'Coy, Foss. 49, f. 1, a beautiful shell, with Rh. sexcostata, M'Coy, are found in Galway, the former also in Ayrshire. Retzia cuneata, Dalm., and Rhynchonella borealis, Schlot., are met with in the South of Scotland, with Rh. Wilsoni. This last-named fossil is thenceforward persistent throughout all the deposits to the Upper Ludlow inclusive. Atrypa (?) Grayii, Dav., Foss. 58. f. 3, and Meristella (?) didyma, Dalm., formerly regarded as Rhynchonellæ, and characteristic Wenlock forms, are found in the upper beds, near Llandovery.

The genus Atrypa is very abundant. A. marginalis, Pl. IX. f. 2, is one of the common fossils of the formation. A. reticularis, Pl. IX. f. 1, and Foss. 15. f. 5, p. 90, appears to have commenced with the Llandovery period, and ranges upwards throughout all the overlying Silurian groups. On the other hand, A. hemisphærica, Pl. IX. f. 3, is confined to the Upper Llandovery beds. This species swarms at Tortworth, Presteign, and Abberley, but is rare in Wales. Spirifer elevatus, Dalm., and Sp. exporrectus, Wahl., are found at Tortworth and May Hill (see Plates IX. & XXI.).

The well-known Lower Silurian Orthides, O. calligramma, Dalm. (not flabellulum), and O. elegantula, Dalm. Pl. IX. f. 19 & 21, are somewhat frequent in the Llandovery rocks, and are also occasionally accompanied by O. Actoniæ, Sow., and O. insularis, Pander. Other species peculiar to these rocks are O. reversa, Salter*, Foss. 49. f. 3, and O. lata, Sow., Pl. IX. f. 23, whilst O. biloba, Linn., and O. elegantula, Dalm., which are Upper Silurian species, are also known in both divisions of this formation.

Of the genus Strophomena, the widely spread S. depressa, Dalm., which ranges from the Llandeilo to the Wenlock rocks, and S. antiquata, Sow., are common in the lower division; S. bipartita, Salt. (S. alternata, Conrad), of Caradoc age, and S. euglypha, Dalm., of the Wenlock deposits, are more rare. In the upper beds, S. compressa, Pl. IX. f. 16, with S. pecten, Foss. 59. f. 3, and an undescribed species, S. arenacea, Salter, MS., are frequent types.

Leptæna transversalis, Dalm., and L. sericea, Sow., Pl. IX. f. 18, both well-known Lower Silurian fossils, with a small species, L. scissa, Salter, MS., are found in both of the Llandovery divisions, the first-named being the most common fossil.

Of Lingulæ there are a few species: L. crumena, Phillips, Foss. 13. f. 5, p. 68, and L. parallela, Phill., are common at Malvern; and there is a species, yet unnamed, in the Lower Llandovery rocks. Discina (Orbicula, Sil. Syst.) is

* M'Coy and Griffith's Synopsis of the Silurian Fossils of Ireland, Appendix, pl. 5. f. 2.

very rare, but the small Crania implicata, Pl. XX. f. 4, is found occasionally in the higher beds.

The above-mentioned Brachiopod Shells are by no means equally distributed throughout the various localities where the Llandovery strata crop out. In the Abberley, Malvern, and Tortworth districts, Atrypa hemisphærica, Sow., is the common fossil, and Pentameri are rare. At May Hill, and round the flanks of the Longmynd, on the other hand, the various species of Pentamerus and Stricklandinia prevail, and are accompanied by Orthis calligramma, Dalm., and O. reversa, Salt., Strophomena compressa, Sow., Spirifer plicatellus, and Sp. elevatus, and, rarely, at May Hill by Chonetes lata, von Buch. The Malvern district is rich in a variety of fossils. Besides the Pentameri, Rhynchonella decemplicata, Sow., Meristella ? furcata, Sow., and several other species of the genus not yet named, we there meet with many fine Lingulæ, which have been above noticed. In the Abberley Hills Atrypa hemisphærica is the common fossil.

The small outlier at Presteign (p. 107) contains few species; but these attain a large size, and Pentamerus oblongus and Atrypa hemisphærica are profusely distributed in it. Along the South-Welsh frontier the upper and lower divisions are marked by their peculiar Pentameri, as already noted, p. 88.

In the cliffs of Marloes Bay, Pembrokeshire, where the Llandovery rocks assume a peculiar mineral structure (see p. 143), the ordinary Brachiopods still prevail. Thus Stricklandinia lirata lies at the base of the Wenlock series, with a thin layer of Pentamerus oblongus underneath. These are in that locality the only representatives of those genera. Rhynchonella decemplicata and a new species with two raised ribs in front, Strophomena compressa, and Atrypa hemisphærica are, however, common. In Galway Orthis calligramma forms entire beds; and the only Pentamerus yet found there is P. oblongus. Atrypa hemisphærica is also there both numerous and of great size; and Orthis reversa, with Rhynchonella serrata, are common. These species also abound in Ayrshire, where Rh. serrata and small forms of Atrypa hemisphærica lie in the upper beds, and a large variety of the latter species, with Meristella angustifrons and Orthis reversa, in the lower. The distribution in Ayrshire is, therefore, like that in South Wales; and the other groups of fossils, as well as the Brachiopoda, follow the same rule.

Lamellibranchiate Shells are not common; but certain species are characteristic of the formation. A long variety of the Pterinea retroflexa, Pl. XXIII. f. 17, is plentiful at Malvern, and also in the Connemara tract of Galway, where two or three other Ludlow-rock forms occur, such as Pt. sublævis, M'Coy, and Pt. bullata, M'Coy, with Pt. lineatula, Sow., Pl. XXIII. f. 16. A small species, perhaps inaccurately referred to the genus, Pt. planulata, Conrad, Foss. 60, f. 6, is not uncommon in the upper beds of the formation; it is a Wenlock species. Cucullella ? ovata and C. antiqua, Sow., are found in Galway.

Two or three rather large species of Ctenodonta occur near Malvern, such as the Ct. lingualis, Phillips, Ct. rhomboidea of the same author, and its variety Ct. deltoidea, Phill. There, too, the remarkable thick species, Ctenodonta Eastnori and Ct. subæqualis, Pl. X. f. 7–9, abound; Ct. ovalis, Pl. XXIII. f. 10, and Ct. subcylindrica, M'Coy, are Galway species. Lyrodesma (Actinodonta) cuneata, Phillips, is characteristic of the Upper Llandovery beds in Pembrokeshire.

A few Mytiloid shells are to be noticed. These are:—Mytilus mytilimeris, Foss. 61. f. 6, at Llandovery and May Hill; two or three species of Modiolopsis at Tortworth; and the small Anodontopsis bulla, f. 5, a species which lived on to the close of the Ludlow rocks, and was first described by M'Coy

from Galway. Orthonota semisulcata, Sow., is recorded by that author from the Ayrshire sandstone, and O. rotundata, Pl. XXIII. f. 5, from Galway; where, too, a solitary species of Pleurorhynchus (Pl. pristis, Salter) has been found.

If the Lamellibranchiate Shells do not present any marked characters, it is otherwise with the Gasteropods, which are numerous and peculiar. Both turbinate and elongate forms abound—such as angular species of Pleurotomaria and Murchisonia, the depressed form Raphistoma (so common in the Lower Silurian), Euomphalus, Trochus ?, Holopea, and Holopella. Macrocheilus, Acroculia, Patella, and even Chiton are also found here. The last is particularly interesting, carrying back, as it does, a marked and common living genus to this Middle Silurian time. It is of so elongate a form that the term Helminthochiton was applied to it by Mr. Salter, who described it so far back as 1846 in Sir R. Griffith's Synopsis of the Silurian Fossils of Ireland. Acroculia Haliotis, Sow., is rare in the upper beds, in which only Euomphalus funatus, Sow., and Eu. sculptus, Sow., so abundant at Tortworth, are found. There are some undescribed species of Turbo—though some shells referred to this genus evidently do not belong to it, being with strong striæ of growth, and raised ridges round the whorls. Such are Trochonema trochleata of M'Coy and T. tricincta, M'Coy, from Galway; and such also may be the thin American shells called Cyclonema by Hall, and of which C. ventricosa of that author is found at Tortworth. The little Turbo tritorquatus, M'Coy, from Llandovery, and also from Galway, may belong to this group; there is but slight evidence, however, that any of the above-named species belong to the genera to which they have been assigned.

The genus Trochus, so-called, contains two, if not three species. T. Moorei, M'Coy, is probably a Pleurotomaria; but the T. multitorquatus of that author, which (or an allied species) appears to occur both in Ayrshire and Pembrokeshire, can scarcely be referred at present to any other genus. It is a most remarkable shell, with at least seven flat whorls. Pleurotomariæ and Murchisoniæ are common fossils. Murchisonia Pryceæ, Sow., and M. angulata, Sow., Pl. X. f. 11, 12, are found throughout the Lower Llandovery of Wales. The inhabitants of these shells seem to have delighted to live upon the sandy and pebbly shoals which, now formed into conglomerate, are so frequent in the hills on the right bank of the Towy. Murchisonia simplex, M'Coy, is found in similar situations, but in a less coarse matrix; it is chiefly a Lower Silurian species. M. cancellatula, M'Coy, is an Ayrshire fossil, and M. pulchra, M'Coy, a Galway species. A large angular shell, to which Mr. Salter applies the MS. name M. bicoronata, is very common at Haverfordwest and in other parts of Wales. Raphistoma lenticularis, Pl. X. f. 10, is everywhere met with in the Llandovery rocks. Two or three species of Holopella (Turritella of my old work) are found in the same zone at Tortworth, and appear to be also the common species of the uppermost Ludlow rock—H. obsoleta, Sow., H. gregaria, Sow., &c. These have been found in Galway too by M'Coy, as well as H. plana, M'Coy. H. tenuicincta of the same author is a Lower Llandovery form, while H. cancellata, Sow., our largest British species, often three inches long, is common to the Lower and Upper Llandovery, and abounds in still higher beds at the Bogmine near Shelve in Shropshire. An angular-whorled Loxonema is found at Marloes Bay; and Macrocheilus fusiformis, Sow., the largest of the Gasteropods of the Llandovery rocks, is a rare fossil from Presteign.

The Pteropods contribute a few species, of which Conularia Sowerbyi, Pl. XXV. f. 10, Ecculiomphalus Scoticus, M'Coy, and a fine species of Pterotheca are the

chief. The last, which much resembles Pt. transversa, Portl., of the Lower Silurian, occurs in the Upper Llandovery rock of Tortworth.

Of Bellerophon, no less than eight species have been already observed, and there are probably many more. The great B. dilatatus, Pl. XXV. f. 6, is found both in Lower and Upper Silurian, as well as in this band. B. bilobatus, Pl. VII. f. 9, so common in the Caradoc sandstone, and so characteristic of the Lower Silurian of France, Spain, and Bohemia, ranges up into the Lower Llandovery in Ayrshire, where B. subdecussatus, M'Coy, and at least two other unnamed species occur. Lastly, B. trilobatus, one of the uppermost Ludlow or Tilestone species, Pl. XXXIV. f. 9, is found both at Tortworth and in Galway.

A few Cephalopoda only have yet been described from these deposits, though they are not rare. Orthoceratites, of both smooth and annulated forms, are indeed often met with. Orthoceras conicum, Sow., of the Sil. Syst. pl. 21. f. 21, is perhaps the most frequent in the upper beds. O. Barrandii, Salter, of Ayrshire, is one of the shortest forms known, and is figured in the Quart. Journ. Geol. Soc. vol. vii. pl. 9. f. 19. O. tenuistriatum of Münster, a species with fine longitudinal striæ, occurs at Haverfordwest and in Ayrshire; and O. bullatum, Pl. XXIX. f. 1, and O. angulatum, Pl. XXVIII. f. 4, are quoted by M'Coy from Galway. Prof. M'Coy mentions five or six smooth species from the Galway beds, including O. tenuicinctum of Portlock. As these species range from Lower to Upper Silurian, it is most important to note this fact in treating of a band which unites those two great divisions.

The most remarkable of all these Cephalopods is Tretoceras bisiphonatum, figured in Pl. XI. f. 5, from the Upper Llandovery rocks of Gorllwyn, near Llandovery, South Wales. It looks like an Orthoceras with a double siphuncle; but (as shown by Mr. Salter *) it has a deep lateral tube piercing the septa, as well as a siphuncle. This remarkable fossil should be sought for by collectors. Lituites cornu-arietis, Sow., a Caradoc species, ocurs in the lower division of these rocks at Llandovery; Cyrtoceras (Orthoceras, Sil. Syst.) approximatum, Pl. XI. f. 4, at Eastnor Park; and a fine large species, yet unnamed, of the latter genus has been obtained from the precipitous strata of Castell Craig Gwyddon, near Llandovery. Lastly, Phragmoceras (?) compressum, Pl. XXXI. f. 4, a Wenlock fossil, has occurred, with many Lower Llandovery species, in the hard sandstones of Thrave, near Girvan, Ayrshire.

Annelida are plentiful, both Tentaculites Anglicus, Pl. I. f. 3, and Cornulites serpularius, Pl. XVI. f. 3–10, being the common fossils in Tortworth and other districts. They are less frequent in the lower division. Tentaculites ornatus, Pl. XVI. f. 11, is rare, but is found in Ayrshire.

Of Trilobites few species are characteristic. If we except Phacops Weaveri, Salter†, a large species of Illænus like Il. Bowmanni, Salt., which is frequent in South Wales, and also occurs in Shropshire and Scotland, there are no forms known to be peculiar to this intermediate formation. Of these species it is remarkable that the Phacops Weaveri is found in beds of corresponding age at Point Gaspè, in the distant region of Canada. The species of Illænus above quoted differs considerably from Il. Bowmanni of the inferior rocks, which, nevertheless, is found here with it. The last-named fossil, with Lichas laxatus, M'Coy, and probably Asaphus latifrons, Portlock, or its closely allied form, are three Lower Silurian species of Trilobites which range into these Llandovery rocks. The other Trilobites are well-known Upper Silurian types, viz. Phacops Stokesii, Edw., and P. caudatus, Brongn. (the former common, the latter rare),

* Quart. Journ. Geol. Soc. vol. xiv. p. 177. † Mem. Geol. Surv. Decade i. pl. 1. f. 16.

Acidaspis Brightii, Murch., and Cheirurus bimucronatus, Murch., with the small Cyphaspis megalops, M'Coy, and Proetus latifrons, M'Coy. The most common of all is Encrinurus punctatus, Brünn., whilst Calymene Blumenbachii, Brongn., which ranges from the Snowdon or Caradoc rocks to the Upper Ludlow, is not unfrequent. Lastly, it is also to be observed that a fragment of Pterygotus was detected by the late H. E. Strickland in the Malvern district.

No traces of Fish-remains have been discovered in British deposits of this age, nor in the overlying Wenlock rocks.

The reader who has perused the preceding details respecting the distribution of organic remains, as well as those former chapters which treat of the ascending series of Silurian deposits constituting the system, will have perceived that the sharp distinction which was at first supposed to exist between the Lower and Upper Silurian rocks no longer holds good. When my classification was proposed in the year 1835, scarcely one of those species which were considered typical of the inferior division had been observed to pass upwards into the superior group; and yet the community of genera convinced me that the whole should be united in one natural system. Seeing that the type shell of the Llandovery and May Hill Sandstones, Pentamerus oblongus, Sow., was never detected in the overlying Wenlock Shale, and was associated with certain species which belonged to the lower part of the series,—and influenced also, to some extent, by mineral characters, I classed the former as the summit of my Lower Silurian rocks.

With the enlargement, however, of the field of examination, not only by the Survey of all Wales, but by researches in Ireland and Scotland, and by the more exact comparison of the fossils, it has become evident that, whilst a great number of species pervade nearly the whole system, the zone so laden with Pentameri, to which the term Llandovery Rocks has been applied, is truly of intermediate character. In short, its inferior member contains many Lower Silurian types, and its superior strata are unquestionably more connected with the Upper Silurian group (of which, throughout many tracts, they form the natural physical base), and are locally transgressive to the inferior rocks. Hence, in the legend attached to the Map, the Lower Llandovery is grouped with the inferior division, the Upper Llandovery, though still characterized by the same Pentameri as the lower mass, being linked on to the superior strata.

It is, indeed, important to give a prominence to this connecting zone by treating separately of its characteristic fossils; for, as will hereafter appear, there are foreign countries (Scandinavia and Russia) in which there is no discordance of strata, and where the stratigraphical and lithological passage from Lower to Upper Silurian is in perfect harmony with the zoological transition above described.

CHAPTER X.

FOSSILS OF THE UPPER SILURIAN ROCKS.

THE reader has already been told that many species of fossils, once supposed to be peculiar respectively to the Lower or Upper Silurian rocks, are now ascertained to be common to both, and necessarily to the intermediate and connecting group.

This datum is the result of the researches of various geologists and palæontologists, whether in the region first explored or in tracts of far greater extent which have recently been paralleled with it. Similar results have, in truth, invariably followed from a full and broad development of the natural geological groups of the Secondary and Tertiary strata, which were described and classified before the older rocks of which we now treat had been brought into order, or even into notice. Thus, for example, when the different members of the Oolitic formations reposing on the Lias were studied in one tract only, as on the eastern coast of Yorkshire, they were seen to be there composed of a series of zones, each of which is sharply separated from the contiguous deposits by fossils confined to it. On tracing, however, the same strata to remote distances, certain remains, which were once viewed as typical of one member only, were found to be common to several subformations, thus combining the whole in one natural system—the Oolitic or Jurassic.

This is just what has happened in the Lower Palæozoic rocks, now that the inferior and superior masses, and the chief formations and subdivisions of Siluria have been ascertained by my cotemporaries to occupy nearly all North and South Wales, large tracts of Cumberland, Westmoreland, and Lancashire, great regions in Scotland and Ireland, and various parts of Europe, America, and Australia.

In short, the two chief divisions, which, from a general similarity, were originally grouped together, have been demonstrated to constitute a natural system, through a community of organic remains. For, even if the contents of the intermediate middle zone of Llandovery rocks be abstracted from the estimate, still there are many species (from fifty to sixty) which range from the Llandeilo and Caradoc into the Wenlock and Ludlow rocks.

The vertical range of all these fossils through the chief Silurian deposits is given at the end of the volume, in a Table prepared by Mr. Salter, with the aid of Professor Morris, and subsequently revised and much augmented by Mr. Etheridge.

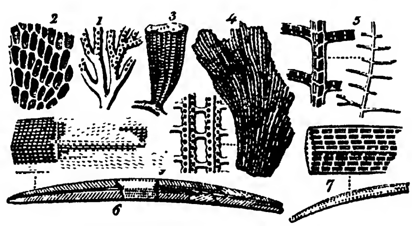
To some of the most striking of these remains which pervade the whole

system, allusion has already been made (Chap. IX.), and notice will now be taken of other forms, of like duration in time, which are more abundant in the upper division. The attention, however, of the reader will be directed chiefly to the types which are peculiarly, and, as far as our present knowledge goes, exclusively, Upper Silurian. (See Plates XIII.–XXXV.)

The Graptolites, which, as before stated, are so very abundant in the shaly and schistose portions of the Lower Silurian of Wales and Scotland, become much more scarce as to species in the Upper Silurian; and though there are many tracts where the Wenlock Shale and Lower Ludlow rocks are crowded with them, it is only one species* (Graptolithus priodon) that is abundant in these upper divisions of the system. When argillaceous sediments abound in these rocks, the Graptolite is rarely absent; but with the cessation of such peculiar conditions this zoophyte, which must have grown on the fine mud at the bottom of the sea, disappears.

One of these Graptolites, which occurs in the old rocks of Snowdon, ranges through the series even to the Upper Ludlow rocks, and hence was named G. Ludensis before it was identified with G. priodon. In the Wenlock Shale, especially towards the base of that deposit, this fossil is sometimes accompanied by a very beautiful and peculiar species—the Retiolites Geinitzianus of Barrande. The latter occupies the same position (at the base of the Upper Silurian series) in Bohemia, whence it was first described. It is a Double Graptolite, like the genus Diplograpsus (see Pl. I. f. 2), from which, however, it differs essentially in having no central axis, and in having the surface composed of a reticular tissue instead of a continuous horny coat. An excellent figure of it is given in M. Barrande's memoir 'On the Graptolites of Bohemia.' Above the Ludlow rocks, and throughout the whole series of overlying Palæozoic strata, no true Graptolite, as before observed, has ever been found; and I repeat, therefore, that this zoophyte is a marked Silurian type.

FOSSILS (50). UPPER SILURIAN POLYZOA.



1. Polypora? crassa (Hornera, Sil. Syst.). 2. Fenestella assimilis (Gorgonia, Sil. Syst.); a common Wenlock species. 3. F. Lonsdalei, D'Orb. (F. prisca, Sil. Syst.). 4. F. Milleri, Lonsd. 5. Glauconome disticha, Goldf. 6. Ptilodictya lanceolata, Goldf., a reduced figure of a full-grown specimen; a part is figured above it, natural size. 7. Pt. lanceolata, in the young state; the cells are longer in proportion.

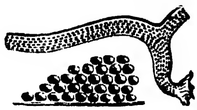
It should further be observed that in Britain neither the Double or foliaceous Graptolite (Diplograpsus) nor the Twin Graptolite (Didymograpsus) is ever met with above the horizon of the Caradoc formation. They are therefore excellent

* Another species has been detected (but only in one locality, where it is plentiful) in strata believed to be of Wenlock age. It is Graptolithus Flemingii, Salter, from Kirkcudbright Bay, where it was first collected by the Earl of Selkirk. See Quart. Journ. Geol. Soc. vol. viii. pl. 21. f. 5, 6.

indices of the Lower Silurian division. In Bohemia, however, as we learn from the work just cited, the foliaceous types are mixed together with the single-sided forms (Graptolithi) in the lower part of the upper division.

The Polyzoa are numerous, but not so numerous in species in the upper as in the lower division. Ptilodictya has been already quoted from the Llandovery rocks (p. 208). A large species, Pt. lanceolata, Foss. 50. f. 6, is abundant in Wenlock strata (f. 7 is its young state); and Pt. scalpellum, Foss. 51, accompanies

FOSSILS (51). AN UPPER SILURIAN POLYZOON.



Ptilodictya scalpellum, Lonsdale (Eschara, Sil. Syst.), natural size. Also a portion magnified. It is a common species in the Wenlock limestone, and grows larger than represented in the figure.

it: the former occurs also in the Ludlow rocks. Glauconome disticha, Foss. 50. f. 5; Fenestella Milleri, f. 4; and F. subantiqua, Foss. 30. f. 1, are common fossils at Dudley. Another common species, F. assimilis, Foss. 50. f. 2, is also figured, as well as the beautiful little cup-shaped Fenestella of the Wenlock limestone, F. Lonsdalei, D'Orb., f. 3. Polypora crassa, f. 1, is not so often met with.

The true Corals (Zoantharia of naturalists) are far more characteristic of the upper than of the lower members of the Silurian rocks, and they are more abundant in them, both as to species and individuals,—the nodular limestone bands of the Wenlock and Aymestry rocks being frequently made up of Corals, or of concretions having coralline bodies as their nucleus or on their surfaces.

When Mr. Lonsdale undertook, at my request, his admirable description of the Corals of the Silurian region, and carefully superintended the drawing of their forms, sixty-two species only were recognizable in our collections; and these included some of the Polyzoa above mentioned, now known as Molluscoidea, and to be closely allied to the Mollusca. But the number of Corals has been greatly increased of late years, chiefly, as regards Britain, by the researches of Professors Milne-Edwards and M'Coy. Several new genera have been formed, which, as they are founded on peculiarities of structure, growth, and reproduction, are likely to prove of permanent value to the zoologist and geologist.

One of the most important of these discoveries, resulting from the labours of Professor Milne-Edwards, and his coadjutor M. Jules Haime*, appears to be, that the majority, if not all, of the Corals of the Silurian system, and indeed of the whole Palæozoic era, belong to divisions of the Coral tribe unknown in modern seas: with rare exceptions, these groups became extinct at the close of the Palæozoic epoch. If this be established, and the large Cup- and Star-corals (Zoantharia rugosa) and the massive Millepores (Z. tabulata) be, as a whole, distinct in structure from the Star-corals and Madrepores of the Secondary and Tertiary rocks and of the existing Coral-reefs, we gain a new fact in the history of animal life upon the globe, which is in harmony with results obtained by the study of the Crustacea, Mollusca, and Fish of the older epochs.

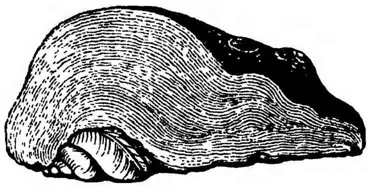
A number of Corals which pass from the Lower to the Upper Silurian rocks have already been enumerated (Chap. VI.); and as these are generally the most abundant species in the younger division, a brief list of them is here given.

The Chain-coral, Halysites catenularius, Foss. 20. f. 6, p. 120, is one of the most frequent; Favosites Gotlandicus, Foss. 18. f. 2, 3; F. alveolaris (F. asper of d'Orbigny), f. 4; F. (Stenopora) fibrosus, f. 7, 8; Heliolites interstinctus (Po-

* Archives du Mus. d'Hist. Nat. vol. v.

rites pyriformis, Sil. Syst.), Foss. 19. f. 4, 5, and the var. H. megastoma, M'Coy (?), f. 3, H. tubulatus, f. 1, and Plasmopora petaliformis, f. 2. Besides these, there is the doubtful fossil, Stromatopora striatella, Foss. 52, usually arranged with the Corals, and much resembling them. Its true position is uncertain; it may even belong to the tribe of Sponges.

FOSSILS (52). UPPER SILURIAN STROMATOPORA.



A section of Stromatopora striatella, d'Orb. (St. concentrica, Sil. Syst.). A very common fossil in the Wenlock Limestone.

In addition to those just quoted, several of the conspicuous Corals of the Upper Silurian strata have already been enumerated, pp. 119, 120. Of the latter it may be truly said that they swarm in the Wenlock Limestone, are found in diminished numbers in the Aymestry rock, and are much less plentiful in the muddy sediments of the Wenlock Shale and Lower Ludlow rock.

Of the prominent species, Favosites alveolaris and F. Gotlandicus are, perhaps, the most generally diffused, and occur in masses varying from the size of a hazel-nut to two or three feet in diameter. The former may easily be distinguished (p. 119, Foss. 18. f. 4) on breaking the mass, by the angles of the tubes being toothed, while those of the other, F. Gotlandicus (f. 2, 3) are smooth-edged regular prisms, on which the double row of pores is very conspicuous. F. cristatus, f. 1, is almost as frequently met with, and forms whole strata on the coast of the Dingle promontory in Ireland. All the three species range, indeed, up to, but not into, the Devonian period *, and are widely distributed over the Northern hemisphere. The various forms of Favosites fibrosus, Goldf., are not less common; but this latter fossil does not appear to be so abundant in the Upper as in the Lower Silurian, or to assume so many variations in form. It is globular, lobed, or branched; and on the slabs of limestone at Dudley there very commonly occurs a narrow branched variety, with numerous small pores intermixed with larger ones. This form is very curious, and is figured in my larger work (Sil. Syst. pl. 15 bis, f. 9)† as a variety of Favosites spongites, Goldf. Professor Milne-Edwards believes it to be of a different genus, and has named it Chætetes Fletcheri, in honour of a gentleman who has long been a judicious collector of the Dudley fossils.

The species called Favosites oculatus, Foss. 18. f. 6, is very abundant in the Wenlock limestone; but it is very doubtful if it be a Coral: it is named Alveolites repens in the work of Milne-Edwards and Haime; but it is probably a Polyzoon, and belongs to Ceriopora.

Next in importance to the Favosites are the large species of the genus Heliolites. Of these, the most common, H. interstinctus, Foss. 19. f. 3, 4, 5, occurs either in globular and pear-shaped masses, or of a flat discoid form, or as a thin incrusting expansion over other Corals and Shells.

Alveolites Labechii, M.-Edw., a Coral two or three inches broad, which looks

* It is right to state that M. Milne-Edwards distinguishes all the Devonian from the Silurian Corals.

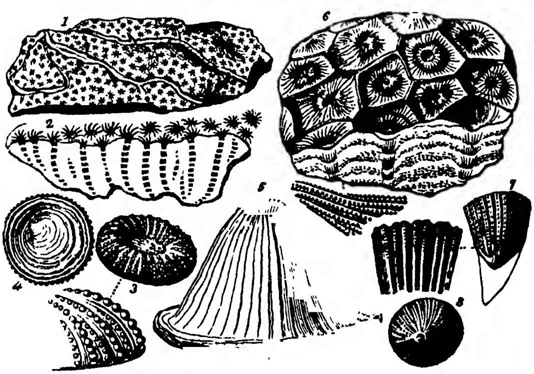
† For a further acquaintance with the Corals of the Wenlock and Ludlow rocks, I must refer the reader to the 'Silurian System,' and the faithful and able descriptions by Mr. Lonsdale. The plates of Corals in that work are reproduced here.

like a small-celled Favosites, and was named F. spongites in the Sil. Syst., is very characteristic. It is known by the oblique or compressed mouths of the cells, Foss. 18. f. 5, p. 119.

Cœnites juniperinus, Foss. 20. f. 3. p 120, may easily be recognized by the curious linear mouths of the cells: this species abounds in the Woolhope Limestone of Presteign, and, with C. intertextus, Eichw. (Limaria fruticosa, Sil. Syst.), may be found on almost every fragment of Wenlock Limestone. Occasionally a fine large species, C. labrosus, Milne-Edwards, occurs at Dudley.

There are several kinds of Tube-corals (such as the Chain-coral or Halysites) and certain species of Syringopora which are abundant. The latter genus is no less curious in its growth than in its structure. When quite young, its divaricating trumpet-shaped tubes creep over the surface of larger Corals and Shells; and in that state it was figured in the 'Silurian System' as Aulopora serpens * (see Foss. 20. f. 2). It next begins to grow upwards; and each open mouth of the tubes lengthens, and becomes a flexuous stem, occasionally throwing out a lateral buttress in concert with its neighbour. These buttresses or buds are hollow, and where they touch each other they coalesce, forming a connecting tube; and the mass, increasing in size upwards, becomes a Syringopora, the tubes often branching, and uniting with those nearest them, until the Coral attains its full size. Syringopora fascicularis, Linn. (S. filiformis?, Sil. Syst.), and S. bifurcata, Lonsd., of which Foss. 20. f. 4, is the lower branched portion, and

FOSSILS (53). CORALS OF THE UPPER SILURIAN ROCKS.



1. Thecia Swindernana, Goldf. (Porites expatiata, Sil. Syst.). 2. A section magnified. 3. Palæocyclus porpita, Linn. (Cyclolites lenticulata, Sil. Syst.), and a magnified portion. 4. Under side of the same. 5. Ptychophyllum patellatum, Schloth. (Strombodes plicatum, Sil. Syst.). 6. Arachnophyllum (Strombodes, M.-Edw.) typus, M'Coy; and a few of its lamellæ magnified. 7. Petraia bina, Lonsdale; the interior cast, and a portion magnified. 8. End view of the same.

f. 5 the ascending stems, are common kinds. 'Aulopora serpens,' 'A. tubæformis,' and 'A. conglomerata' of the 'Sil. Syst.' are the young or basal portion of one or other of these species. There are one or two rarer forms—Thecia (Agaricia) Swindernana, Foss. 53. f. 1, and Labechia conferta, Lonsd. (Monticularia, Sil. Syst.)—not so obviously belonging to the group we have just noticed, viz.

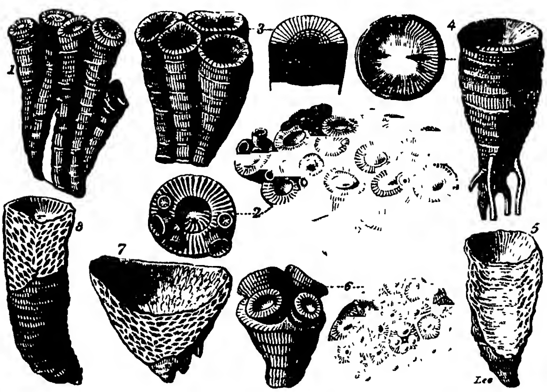
* [Milne-Edwards and Haime have shown these to be the young of Syringopora. Prof. E. Forbes had been of the same opinion for some years, but had not published it.—J. W. S.]

the Zoantharia tabulata of M.-Edwards and Haime, to which the Thecidæ, the Favositidæ, and the Milleporidæ belong.

The Palæocyclus of Milne-Edwards was considered by that naturalist to belong to the family Fungidæ, which includes the modern Mushroom-corals, and was supposed to be the only Silurian (or, indeed, Palæozoic) form of the group Aporosa*—that group which is the most prevalent in modern seas. Palæocyclus porpita, Linn. (Cyclolites lenticulata, Sil. Syst.), is the one figured, Foss. 53. f. 3, 4; and there are other species, P. præacutus, Lonsdale, and P. rugosus, M.-Edw., in the Wenlock rocks at Dudley.

All the Cup-shaped Corals of the Palæozoic series, of which about fifty species occur in Silurian rocks, belong to the section Zoantharia rugosa†, distinguished in general, like the other great group (Z. tabulata), by the development of the transverse plates or tabulæ in the body of the Coral (see the following woodcut), and including both simple cup-like forms, such as Omphyma subturbinata, Foss. 54. f. 4, Cystiphyllum Siluriense, f. 7, Petraia bina, Foss. 53. f. 7, 8—and branched or

FOSSILS (54). CUP-CORALS OF THE WENLOCK LIMESTONE.



1. Cyathophyllum articulatum, Wahl. (cæspitosum, Sil. Syst.). 2. C. truncatum, Linn. (Cyathoph. dianthus, Sil. Syst.); and a single cup, with its marginal disk-buds attached. 3. Strephodes vermiculoides, M'Coy. 4. Omphyma subturbinata, D'Orb.; and a view of the cup with its four basal pits. 5. A longitudinal section. 6. Acervularia ananas, Linn.; and a cup, natural size, with four young buds. 7. Cystiphyllum Siluriense, Lonsdale. 8. C. cylindricum, Lonsdale.

composite forms, Cyathophyllum articulatum, Foss. 54. f. 1, and C. truncatum, f. 2. When such compound Corals have grown closely together, so that the separate corallites or cups press one another into angular forms, masses are produced, such as Acervularia ananas, f. 6, and Arachnophyllum typus, Foss. 53. f. 6. The latter is now called Strombodes by Milne-Edwards and Haime.

Among these common species, two are remarkable for the mode of propagation of their buds or young corallites.

In Cyathophyllum truncatum, Linné (C. dianthus, Sil. Syst.) just quoted, the young buds take their origin from the inner edge of the parent polype-cup (Foss. 54. f. 2), and the young Corals thus produced quite overtop, and at length cover over the parent, until in their turn they, too, produce their young clusters

* Recent investigations by Dr. Martin Duncan and Dr. Lindström have, however, determined this Coral to belong to the Rugosa, thus restricting the Aporose Corals to the Mesozoic and Cænozoic periods.

† See Note, p. 221.

through this marginal 'calicular' development; and this process is frequently repeated in the upward growth of the Coral. (See the larger figure.)

Another species, so like the former that in some conditions it might easily be mistaken for it, is Acervularia ananas (A. luxurians, Eichwald), described by Linné * and Fougt from rocks in Gothland which are now known to be Upper Silurian. A single cup is represented (Foss 54. f. 6), which has given birth, by fissiparous division, to four young corallites, which take their rise, not from the margin, but from the centre of the old Coral, the life of the parent being thus continued in the offspring. (See Lonsdale in 'Sil. Syst.' pl. 16. f. 6.). As a number of these buds grow up together, they stunt each other's growth in a lateral direction; and as the process of multiplication is often repeated, the corallites by mutual pressure are forced into an angular form like the cells of a honeycomb; their edges grow together, and the result is a compound mass of stars †. (See the right-hand figure.)

There are several other Cup-shaped Corals which are frequent in the upper division, and especially in the Wenlock Limestone; but they are not so characteristic as those just mentioned:—Omphyma turbinata, Linn., O. Murchisoni, Milne-Edw., Cystiphyllum cylindricum, Lonsdale, C. Grayi, Milne-Edw., and C. brevilamellatum, M'Coy; Cyathophyllum angustum, Sil. Syst. pl. 16. f. 9, C. trochiforme, M'Coy, Strephodes vermiculoides, Foss. 54. f. 3 (Strombodes diffluens, Milne-Edw.), Ptychophyllum patellatum, Foss. 53. f. 5 (a remarkable species, in which the elevation of the centre of the cup is so great as to give the Coral a reversed appearance, the base being nearly flat), Clisiophyllum vortex, M'Coy, and Goniophyllum Fletcheri, M.-Edw., a four-sided Coral, very like one found in the Isle of Gothland, Sweden. Some Cup-corals also are common to Gothland and Britain, such as Aulacophyllum mitratum, Hisinger, and Cyathophyllum Loveni, M.-Edw., besides the two species of the latter genus before mentioned ‡; and there are some which extend their range to America.

The Ludlow rocks, being for the most part mudstones, do not often contain many Corals; but in their calcareous portions one or other of the species above described occur §. Prof. M'Coy has added Cyathaxonia Siluriensis to the scanty Ludlow list; it is from Kendal. Favosites fibrosus, Goldf., indeed, is very common in the form of an incrusting envelope upon the spiral shells Cyclonema and Murchisonia (see p. 132 and p. 119, Foss. 18. f. 8). Together with Favosites asper, d'Orb., and some few others, it seems to have been indifferent to the nature of the sediment it lived upon; they are found throughout the system. The little Palæocyclus appears to have lived indifferently on a calcareous, muddy, or gravelly bed. Petraia bina seems to have preferred a muddy habitat; but most species of this genus are chiefly found in sandstones ‖.

Note.—On the 'Zoantharia rugosa,' and their operculated forms in particular, G. Lindström, Ph.M. of Wisby, Gothland, thus writes (Œfversigt af Vetenskaps Akad. Förhandlingar, 1866; and Geol. Mag. 1866):—"Professor Steenstrup some years ago questioned the fact as to whether the Zoantharia tabulata and Z. rugosa, included by him

* Amœnitates Academicæ, vol. i. p. 196 &c.

† The growth and reproduction of Corals has of late years been much studied, and well illustrated by Dana, Milne-Edwards, Fromentel, Michelotti, Duncan, and other naturalists.

‡ So many of the Wenlock Corals are found in the limestone of Gothland in the Baltic, that the stratum might have been identified by them alone —Heliolites interstinctus, Favosites alveolaris, F. Gotlandicus, F. cristatus, Cœnites juniperinus, Halysites catenularius, Syringopora fascicularis, Omphyma turbinata, Ptychophyllum patellatum, Acervularia ananas, &c. These species are well figured by Hisinger.

§ This relation of Corals to Limestone is one of the facts most prominently shown in the very valuable Tables of the relationship of the organic remains and sedimentary materials of the Silurian rocks both of North America and Wales, in Dr. Bigsby's elaborate memoir on the distribution of the rocks and fossils of the Palæozoic area of New York State, compared with that of Wales and other regions. Quart. Journ. Geol. Soc. vol. xv. p. 295.

‖ See also Dr. Bigsby's Tables of fossils and sediments referred to above.

under the common name of 'Cyathophylla,' should be regarded as true Polyps. MM. Edwards and Haime, in framing those great subdivisions of their 'Coralliaria,' remarked their striking dissimilarity to the other Actinozoa. Professor Agassiz, in his grand Monograph on the Acalephæ of North America, considers these differences so important that henceforth all connexion between the above-named groups and the Zoantharia aporosa and Z. perforata will be impossible. But besides these peculiar characteristics of the Z. rugosa . . . . several are provided with an operculum of very strange shape. . . . . Several of these operculated fossils have been placed with the Brachiopoda and other classes." M. Lindström carefully describes and figures Goniophyllum pyramidale (Turbinolia, Hisinger), Rhizophyllum Gotlandicum (Calceola, F. Rœmer), Calceola sandalina, Hallia calceoloides, &c., and he brings together information relating to the operculum and other features of Cyathophyllum, Hypodema, Cystiphyllum (?), Cyathaxonia (?), &c., and offers the following conclusions:—1. That the Rugosa must be separated from the Actinozoa, or the true Corals; 2. That they form a class of their own in the great division of Radiata; 3. That Goniophyllum pyramidale is an undoubted Rugosum, in its shell and in its operculum, and that it coincides with the three species of the old genus Calceola, and that these are no longer to be numbered amongst the Brachiopoda, but are Rugosa. M. Lindström is inclined to agree with Agassiz that the Rugosa had close relation with the existing Lucernariæ.

Of Cystidea the forms are rare, but remarkable and characteristic, the species in the Upper Silurian being all furnished with what Edward Forbes called 'pectinated rhombs.' The fine species shown in Foss. 55. f. 1, has three of these curious markings, the usual number possessed by British Upper Silurian forms; while they are often much more numerous in those few Lower Silurian genera which possess them at all. The nature of these rhombs is not yet fully understood. The following species of Cystidea have been collected at Dudley by Mr. Gray and Mr. Fletcher * of that neighbourhood:—Pseudocrinites magnificus, f. 1; P. quadrifasciatus, f. 2; P. bifasciatus, and P. oblongus, Forbes †; Apiocystites pentremitoides, f. 4; Prunocystites Fletcheri, f. 3; Echino-encrinites baccatus, f. 5, and E. armatus, f. 6. Under the upper right-hand figure, one of the curious 5- or 6-valved ovarian openings is shown, and the two halves of a pectinated rhomb, occurring, as usual, opposite each other on neighbouring plates.

FOSSILS (55). CYSTIDEA OF THE WENLOCK LIMESTONE.

1. Pseudocrinites magnificus, Forbes. 2. P. quadrifasciatus, Pearce. 3. Prunocystites Fletcheri, Forbes. 4. Apiocystites pentremitoides, Forbes. 5. Echino-encrinites baccatus, Forbes. 6. E. armatus, Forbes; with its ovarian pyramid and a rhomb.

The genus Echino-encrinites, but with different species, is found in the Lower Silurian rocks of Russia. In North America, the representative of the Wenlock Limestone (the 'Niagara group' of New York) contains some characteristic Cystidea of similar forms.

Passing on to the great group of Crinoid animals, which are numerous but rarely perfect in our Lower Silurian division, we find the Upper very rich in forms of this class. Many of these are yet undescribed, and we can only, at present, refer to those figured in our Plates XIII.–XV., and to a few other species that have been published in the works of Austin, d'Orbigny ‡, &c.

* Mr. Gray's Collection is now in the British Museum, and Mr. Fletcher's in the Woodwardian Museum.

† Memoirs Geol. Surv. vol. ii. pt. 2. pp. 496 *et seq.*

‡ Austin, Monograph of the Crinoidea, 1844; d'Orbigny, Prodr. de Paléontol. Universelle, 1849.

By far the commonest fossil of this class is the Periechocrinus moniliformis (Actinocrinus, Sil. Syst.), Pl. XIII. f. 1, 2, the long, bead-like stems of which cover the slabs of Dudley limestone, and sometimes attain five feet in length. This and the following species have the arms composed of a double row of plates set side by side:—Dimerocrinus decadactylus, Pl. XIII. f. 5; D. icosidactylus, f. 4, a common fossil; three species of the singular genus Eucalyptocrinites, Goldfuss (Hypanthocrinus, Sil. Syst.), found in the Dudley limestone, viz. E. decorus (Pl. XIV. f. 2), E. polydactylus, M'Coy (a very large species), and the rare E. granulatus, Lewis (as yet detected only at Walsall in Staffordshire); and, lastly, Marsupiocrinites cælatus, Pl. XIV. f. 1. A reduced copy of a perfect specimen of this fossil is given, Foss. 56. f. 1; and at f. 3 the same species is drawn without the arms, but showing the long proboscis inserted into the shell of a Gasteropod Mollusk, Acroculia haliotis. This shell is better figured in Pl. XXIV. f. 9.

From the very frequent occurrence of the same shell, tightly embraced by the arms of this Crinoid, and from the fact that the mouth of the shell is always turned downwards over the proboscis, it is inferred that it was the habitual food of the Encrinite. This has long been observed by Mr. John Gray of Dudley, who has dissected many specimens from the stone; and they are to be seen in his collection, now in the British Museum. It has also received confirmation from the American naturalists Yandell and Shumard, who observed the same habit in several of the Silurian Crinoids of America.

Of those species which have only a single row of joints in each arm, Taxocrinus (Cyathocrinus) tuberculatus is the most common. It occurs of all sizes, from the minute specimen represented in Pl. XIV. f. 6, to much larger forms than f. 5. Taxocrinus tesseracontadactylus, f. 4, and T. Orbignyi, M'Coy, are rarer forms, the former being found also in Gothland. Cyathocrinus goniodactylus, f. 3, C. arthriticus, f. 7, and C. capillaris, Pl. XV. f. 3, are common Dudley fossils. Ichthyocrinus pyriformis, Mill., often grows larger than it is represented in Pl. XIV. f. 8; and this species extends its range to North America. Platycrinus* retiarius, Pl. XIV. f. 9, when perfect, has a long stem with many auxiliary arms. Fine specimens are in the Museum of Practical Geology.

Enallocrinus punctatus, Hisinger, which occurs both in England and Sweden†, is frequently found in the Wenlock Limestone of Wenlock Edge.

Glyptocrinus? expansus, Pl. XV. f. 1, is perhaps one of the most stately species, conspicuous for the size to which it grows, and for the numerous plates of which its body or cup is composed.

Lastly may be noted a very common Wenlock fossil, Crotalocrinus rugosus, Foss. 56. f. 4–7, whose structure is, perhaps, more remarkable than that of any other Silurian Crinoid.

In most Encrinites the arms issue immediately from the edge of the pelvic‡ cup, commencing with a single joint, and soon branching into two, three, or four, the subdivision varying in different species. But in this remarkable Encrinite, the upper edge of the pelvis is seen to be surmounted by at least twenty or twenty-five arm-joints, instead of the usual five; and when the specimens have lost all but the pelvis and these lower joints, the latter are seen (Foss. 56. f. 5) each to have a perforation in their middle as in the arm-joints of all other Crinoids. These multitudinous arms soon divide, and subdivide again and

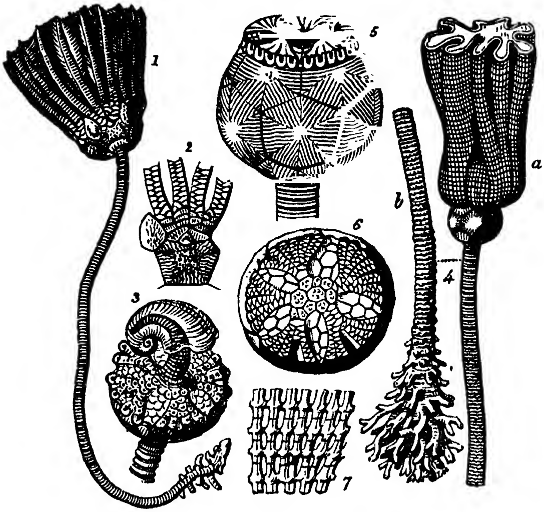
* Professor de Koninck, on a survey of the British Silurian Crinoidea at Dudley, decided that there are several Carboniferous genera among them.

† See Hisinger, Lethæa Suecica, pl. 25. f. 2.

‡ A better nomenclature than that of Miller's (basal plates, radial and interradial plates, &c.) is now adopted. See Professor M'Coy in Pal. Foss. Woodw. Mus.; De Koninck et Le Hon, in 'Les Crinoïdes Terr. Carb. Belgique,' 1854.

again, the several branches lying close side by side, and leaving scarcely any free space between them. Each joint gives off from either side a small lateral process, f. 7, which unites with that of its next neighbour; and this is continued through the whole extent, so that the several joints of the contiguous rays are

FOSSILS (56). CRINOIDEA OF THE WENLOCK LIMESTONE.



1. Marsupiocrinites cælatus, Phil. 2. Magnified base of the arms. 3. Proboscis of the same inserted in the shell of Acroculia haliotis. 4. Reduced figure of Crotalocrinus rugosus, Miller; the bag-like cluster of arms surmounting the small, round 'pelvis.' 5. The latter, of the natural size, with the stomach-plates stripped off, and showing the base of the many-fingered arms. 6. The flat stomachal surface, showing also the branching of the arms from their bases. 7. A part of the reticulate congeries of fingers, each joint being anchylosed to its neighbour on either side.—[J. W. S., 1859.]

all securely fixed to each other. Instead, therefore, of a star of free and waving arms, a deep and wide funnel is formed, like a wicker basket; or rather (as the joints are all of equal length, and the lateral processes range in continuous transverse lines) the texture is like that of a piece of the coarsest-woven serge or canvas, f. 4 *a*. This curious funnel of anchylosed arm-joints, therefore, was either flexible or grew in a lobed and puckered form *. But although, as before said, the numerous arms seem to start at once from the pelvis, their real origin is on the ventral surface further inward: see f. 6, where they commence with single joints, as in other crinoids, and are clothed with short tentacles to their very base. This surface is but rarely visible, the usual appearance of the cup being that which is seen in f. 5, and in Pl. XIII. f. 3, which figures are of the natural size. The cup consists of fifteen plates. The stem, f. 4 *b*, was long ago figured by Parkinson in his 'Organic Remains'†. It is made up of close joints, each with a row of tubercles, which are perforated, the hole communicating with the central canal of the stem. Near the root, these tubercles lengthen out into

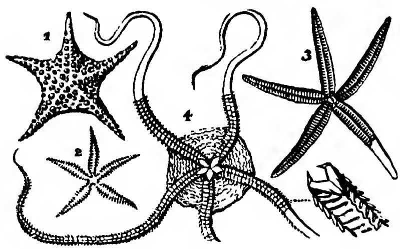
* Since the first edition of this book was published, we have seen Müller's beautiful figures of a very similar genus (Anthocrinus Loveni) from the Isle of Gothland. In all probability there were in our species, as in his, five reticulate arms, overlapping each other, and highly convoluted, but not forming a continuous funnel. (Ueber den Bau der Echinodermen, pl. 8: Berlin, 1854.)

† 'Turban or Shropshire Encrinite,' vol. ii. pl. 15. f. 5. p. 193.

cylindrical tubular processes, which attached the Crinoid to Shells and Corals. The cabinets of my friends Mr. Fletcher and Mr. Gray furnished the materials to Mr. Salter for the illustration and description of this remarkable fossil.

Asteriadæ, or Starfishes, are by no means rare in the Upper Silurian, four species, which are here figured, having been long ago found in the Ludlow rocks of Kendal. The most common is Palasterina primæva, Foss. 57. f. 1. Palæaster Ruthveni, f. 3, and Palæaster hirudo, f. 2, are less abundant. The rare fossil Protaster Sedgwicki, f. 4, was thought by Professor E. Forbes to be closely related to certain species of the group of Euryales, now inhabiting the northern seas; but better specimens of the genus, since obtained (p. 127), show it to have been an abnormal form of the Ophiuridæ, from which it differs in having a double instead of only a single row of plates above and below. This genus Protaster, which first appears in the Lower Silurian strata, has been found abundantly in the grey, fine-grained flagstone of the Lower Ludlow rock. In Shropshire, P. Miltoni, Salter, nearly a foot wide from tip to tip of the rays, and a small, graceful species, P. leptosoma, Salt., have been discovered*, together with four or five species of Palæocoma, a Starfish which greatly resembles the common red Bird's-foot Sea-star (Palmipes roseus) of our coasts. One species, Palæocoma pyrotechnica, Salt., has stiff club-shaped spines like those of the living Cushion-stars. Lastly, there is a Starfish in the Dudley limestone, named Lepidaster Grayii † by Professor Forbes, more crinoidal in its aspect than any existing species.

FOSSILS (57). UPPER SILURIAN STARFISHES.



1. Palasterina primæva, Forbes. 2. Palæaster hirudo, Forbes. 3. P. Ruthveni, Forbes. 4. Protaster Sedgwicki, Forbes. (All from the Upper Ludlow rocks in the neighbourhood of Kendal, and first found by Professor Sedgwick.)

I have thus dwelt particularly on a few of the radiate animals, because they present us with some new or little-known characteristics of the Silurian rocks. The remaining groups, Mollusca, Annelida, and Crustacea, do not call for quite so much detail.

The nomenclature of one group of the Mollusca is being thoroughly revised by Mr. T. Davidson, in his important Monograph on the British Silurian Brachiopoda‡.

Brachiopod Shells, though not in such great preponderance, nor so numerous in species, as in the Lower Silurian rocks, are yet very abundant. Pentameri are still present; but they are mostly distinct from the Llandovery species. Whilst Orthides are in much less quantity than in the inferior zones, Rhynchonellæ and Spiriferi occur very frequently; and of Lingulæ there are decidedly fewer species than in the Lower Silurian.

Several characteristic Brachiopods have been quoted as ranging from the Lower to the Upper Silurian, such as Orthis elegantula, O. biforata, and O. biloba,—the first of these being equally abundant in both divisions. Though also occurring in both, Strophomena depressa, Dalm., and S. pecten, Linn., Leptæna

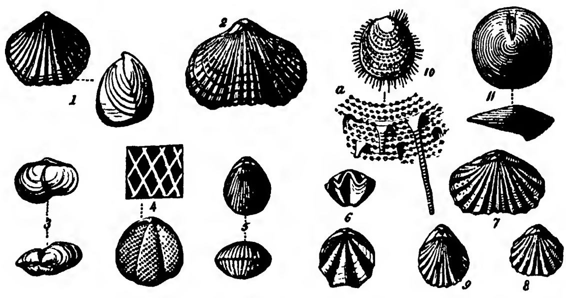
* Salter, in Ann. & Mag. Nat. Hist. 1857, vol. xx. pp. 330, 331.
† Mem. Geol. Surv. Decade iii. pl. 1.
‡ Palæontographical Society's Monographs, 1866.

transversalis, Dalm., Atrypa marginalis, Dalm., and A. reticularis, Linn., are far more abundant in the Wenlock than in any of the lower strata, except the Llandovery rocks. The last-named species ranges no lower than the Llandovery strata; and the same may be said of Spirifer exporrectus, Wahl.*, Sp. plicatellus, Sow., Pl. XXI. f. 2, Retzia cuneata, Dalm., and Rhynchonella borealis, Schl.; and they are rare below the Wenlock shale. These species have a wide geographical range. In Chapters VI. and VII. thirty species are enumerated from the various strata of the Upper Silurian rocks, among which Leptæna transversalis, Strophomena euglypha, Spirifer elevatus, Sp. plicatellus, and Pentamerus galeatus are most characteristic of the Wenlock strata; Rhynchonella Wilsoni, Rh. nucula, Rh. navicula, Orthis lunata, and Chonetes lata chiefly distinguish the Ludlow rocks. Yet in some localities Rhynchonella navicula and Chonetes lata are prevalent in the Wenlock strata—the former near Builth, the latter on the west coast of Ireland.

The species above enumerated are drawn in Plates XX.–XXII. There are, however, several others which must be noticed. Among the rarer Wenlock species may be reckoned Discina Morrisii of Davidson, D. Verneuilii, Dav., Orbiculoidea Forbesii (Foss. 58. f. 11), and Crania implicata, Pl. XX. f. 4. Discina rugata, Pl. XX. f. 1, 2, and D. striata, f. 3, are common Ludlow forms.

Siphonotreta Anglica, Foss. 58. f. 10, is a rare fossil. This genus is characteristic of the lowest Silurian rocks in Russia. The genus Obolus, also very characteristic of the same Lower Silurian near St. Petersburg, has, through the

FOSSILS (58). UPPER SILURIAN BRACHIOPODA.



1. Rhynchonella nucula. 2. Rh. Lewisii, Davidson. 3. Atrypa Grayii, Davidson. 4. Retzia Bouchardi, Dav. 5. R. Barrandii, Dav. 6. Porambonites Capewelli, Dav. 7. Retzia Salteri, Dav. 8, 9. Variety of the same (var. Baylei, Dav.). 10. Siphonotreta Anglica, Morris; *a*, portion of the surface, with the annulated spines, magnified. 11. Orbiculoidea Forbesii, Davidson.

acumen of Mr. T. Davidson, been recognized in the Wenlock Shale of Dudley and Walsall. The British species, Obolus Davidsoni, and its var. transversus, Salter†, is a larger form than those of Russia. With such constantly augmenting data for connecting them, it is obviously impossible to divide the Silurian rocks into two natural systems.

Spirifer exporrectus, Wahl., is frequent in the Woolhope Limestone and Lower Wenlock Shales. Sp. sulcatus, Hisinger, is a small species common on

* Wahlenberg gave the fossil this name before Hisinger and Dalman termed it 'trapezoidalis.'

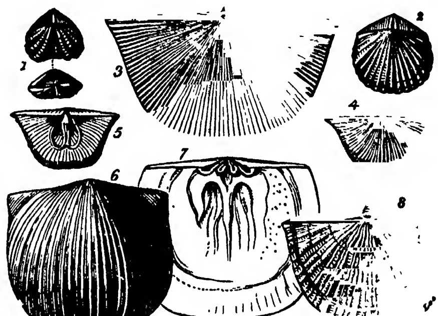
† They are figured and described as Upper Silurian fossils in Mr. Davidson's Monograph (vol. i. Introd. p. 136), Palæontographical Society's Monographs, 1854.

Wenlock slabs; Meristella Circe, Barr., a Bohemian fossil, occurs with the common Meristella tumida at Walsall; Retzia Salteri (Foss. 58. f. 7) and its var. Baylei (f. 8, 9), Rhynchonella Lewisii (f. 2), and Retzia Bouchardi (f. 4) are common Wenlock species; R. Barrandii, f. 5, Porambonites Capewellii, f. 6, and Atrypa Grayii, f. 3 (a strange twisted species), are rare Dudley fossils. Rhynchonella nucula, f. 1, is the commonest of all the Rhynchonellæ of the Upper Ludlow rock. Imperfect specimens of it are figured in Pl. XXII. f. 1, 2.

Three Pentameri only were formerly described from the upper division, namely P. linguifer, P. galeatus, and P. Knightii (see Plates XXI. & XXII.). To these may now be added Stricklandinia (Pentamerus) lirata, Foss. 15. f. 3, p. 90, found in the Woolhope limestone, which may be considered to be strictly a transitional species, occurring in the very lowest beds of this division, and in the uppermost strata of the Llandovery formation, at May Hill, Gloucestershire, at Presteign, and also in Pembrokeshire.

Some species of Orthis have been already quoted, Chap. VI., as very common

FOSSILS (59). UPPER SILURIAN BRACHIOPODA.



1. Orthis Bouchardi, Davidson. 2. O. calligramma, Dalm. (O. Davidsoni, de Vern.). 3. Strophomena pecten, Linn. 4. Str. funiculata, M'Coy. 5. Interior of the same. 6. Str. imbrex, Pander. 7. Interior of dorsal valve of the same. 8. Str. antiquata, Sow., full-grown (half the natural size).

in the Wenlock and Dudley limestone. O. Bouchardi, Davidson *, Foss. 59. f. 1, O. Lewisii, Dav., and O. æquivalvis, Dav., are rare in the same formation; and so is O. calligramma, Dalm., adverted to at p. 192, if the shell here figured, Foss. 59. f. 2, be not a distinct species (O. Davidsoni) as de Verneuil and M'Coy suppose.

Strophomena antiquata, Foss. 59. f. 8, grew five or six times the size of the figure in my original work (see Pl. XX. f. 18). Strophomena funiculata, f. 4, and Str. imbrex, f. 6, 7, are common Wenlock species. Str. corrugata, Portlock, is a beautiful but rare Wenlock shell, which has been already cited in the Lower division, where it is plentiful. Str. pecten, f. 3, though common both in Lower and Upper Silurian, escaped notice when the 'Silurian System' was published. Str. applanata, Salter, a small species resembling the last, occurs sparingly in both divisions.

Lingula Lewisii, Pl. XX. f. 5, is one of the commonest species of the Middle

1848

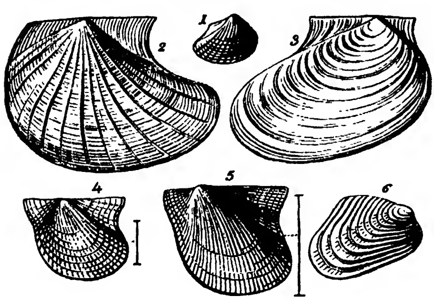
British Upper [illegible] cluding a great many not before described. The reader will find a single Productus described [illegible] perfect Strophomena depressa, a common Silurian species.

Ludlow or Aymestry rock; and L. cornea, Pl. XXXIV. f. 2, abounds in the Tilestone of the Upper Ludlow. They are both well-marked species, and, with their congener L. minima, Sow., and the small but characteristic L. lata, Sow., L. striata, Sow., and L. Symondsi, Salter, of the Lower Ludlow rock, are all the species of the genus known in the Upper Silurian of Britain. The long-oval species, called after my esteemed friend the Rev. W. S. Symonds, of Pendock, ranges from the Upper Llandovery to the Ludlow rocks, and is a common species at Malvern, and at Buildwas in Shropshire.

The Lamellibranchiate Bivalves, though numerous in species, have not yet been fully described. They consist chiefly, as Prof. Phillips has pointed out *, of one or two closely related families, which are represented by the living forms Mytilus, Arca or Nucula, and Avicula. When strictly defined, the more modern genera Pullastra, Mya, Cypricardia, and Cardium, to which several of these forms were referred in the original Silurian work, are now found not to have existed in these early geological times.

Forms of the genus Pterinea (Avicula, Sil. Syst.) abound. Pt. retroflexa, Wahl., Pl. XXIII. f. 17, a species subject to great variation, has already (pp. 99, 121 &c.) been quoted from various strata. Pt. Sowerbyi, M'Coy, f. 15, charac-racterizes the Aymestry limestone and Ludlow rocks, whilst Pt. lineatula, Sow., f. 16, is very frequent near Ludlow. Besides these common species, Prof. M'Coy has enumerated several others—namely, Pt. Boydii, Pt. demissa, Pt. pleuroptera, and Pt. subfalcata all of Conrad, and Pt. tenuistriata, M'Coy, Foss. 60. f. 5. The last three are, it is believed, also found in Lower Silurian rocks in Wales and Westmoreland. Others are upper Silurian forms only; such as Pt. hians, M'Coy, an Aymestry rock fossil, and Pt. asperula, M'Coy, f. 4, a fossil from the Wenlock shale at Builth. A common Wenlock species, doubtfully referable to this genus, is Pt. planulata, Conrad, Foss. 60. f. 6. Many species, however, of this age, particularly those from Pembrokeshire and Ireland, are, as yet, imperfectly known. The district of the Dingle in Ireland, for example, is rich in fossils of this group. Of these, Pt. orbicularis, M'Coy, is one of the largest and most plentiful. Pt. posidoniæformis and Pt. fimbriata are described by the same author; and there are other species, with several fine varieties of the common Pt. retroflexa, Wahl., in that prolific locality.

FOSSILS (60). UPPER SILURIAN LAMELLIBRANCHIATA.



1. Pleurorhynchus æquicostatus Phill. 2, 3. Avicula Danbyi, M'Coy 4. Pterinea asperula, M'Coy. 5 Pter. tenuistriata, M'C. 6. Pter. planulata, Conrad.

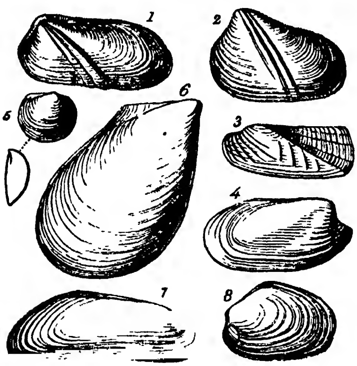
Other large species, more resembling Avicula, or Aviculopecten, such as A Danbyi, M'Coy, Foss. 60. f. 2, 3, and A. ampliata, Phill., occur in the Uppe Ludlow rock; whilst Pterinea (Avicula) mira, Barr., a beautifully reticulate

* Mem. Geol. Surv. vol. ii. pt. 1. p. 264.

species, which is common at Dudley, is identical with one from the Upper Silurian of Bohemia.

Next in importance are the Mytiloid Shells, represented by the genus Modiolopsis *, which contains several species. Thus M. complanata, Pl. XXIII. f. 1, is an Upper Ludlow fossil; M. Nilssoni, Foss. 61. f. 8, is both a Wenlock and Ludlow species; and M. platyphyllus, f. 7, is characteristic of the uppermost Ludlow beds, where it occurs with some other forms, now referred by Professor M'Coy to his new genus Anodontopsis. To this group, which contains the more circular forms of the genus, belong Anodontopsis (M.) quadratus and A. ovalis, Salter, A. angustifrons, M'Coy, A. lævis, Sow., and A. bulla, M'Coy, Foss. 61. f. 5. They are all species of the Ludlow rock. Mytilus exasperatus, Phill., and Modiolopsis antiqua, Pl. XXIII. f. 14, are Wenlock fossils, the latter being common. Mytilus mytilimeris, Foss. 61. f. 6, is also plentiful in the Wenlock rocks. Goniophora cymbæformis, Pl. XXIII. f. 2, seems nearly allied to Mytilus, and is one of the most abundant Upper Ludlow shells. Certain forms, less evidently related to this family, have been termed Orthonota by some authors, and Sanguinolites by others. They are thin shells, without hinge-teeth, and outwardly much resemble Mya, Panopæa, &c., to which, however, they are not in reality at all allied. Orthonota semisulcata (Modiola, Sil. Syst.), is one example from the Ludlow rocks, not figured in this work; and O. prora (Foss. 61. f. 4), is one of the most frequent fossils in the Tilestones of Westmoreland. Other species referred to this genus in the publications of the Geological Survey † differ still

FOSSILS (61). UPPER SILURIAN LAMELLIBRANCHIATA.



1. Grammysia cingulata, Hisinger. 2. G. triangulata, Salter. 3. Orthonota angulifera, M'Coy. 4. O. prora, Salter (O. semisulcata, M'Coy). 5. Anodontopsis bulla, M'Coy. 6. Mytilus mytilimeris, Conrad. 7. Modiolopsis platyphyllus, Salter. 8. M. Nilssoni, Hisinger,

more widely in outward appearance from Modiola, to which they are nevertheless believed to be related. They are abundant in the Ludlow rocks, especially O. amygdalina, Pl. XXIII. f. 6, and its variety retusa, f. 7. This species often covers the surfaces of the uppermost stratum of the Upper Ludlow rock, to the exclusion of all other fossils; and with it, more rarely, occur O. impressa, Pl. XXIII. f. 3, and O. undata, f. 4. But Orthonota rotundata, f. 5, O. solenoides, f. 9, and O. rigida, f. 8, are more common in the Lower Ludlow. O. angulifera, Foss. 61. f. 3, is an ornamented species, rare in the Ludlow rocks of Westmoreland, and looking like the Goniomya V-scripta of the Oolite.

Grammysia, de Verneuil, is a genus resembling the shells last mentioned, but

* [There does not appear, however, to be any decided character to separate these shells from the Modiolæ of our own day.—J. W. S., 1859.]

† Memoirs, vol. ii. pt. 1. p. 360.

easily recognized by the deep furrows on its valves. G. triangulata, Foss. 61, f. 2, is a typical Tilestone fossil, and G. cingulata, f. 1, as well as G. extrasulcata, Salter, are found with it, both in South Wales and Westmoreland. The last-named is equally common in other Upper Silurian strata (Wenlock), at Dudley, Usk, and near Llandeilo, and is also found in Gothland, Sweden, and Norway. It appears to have flourished best on a sandy sea-bottom—a condition apparently most favourable to the Lamellibranchiata in general.

Cardiola interrupta, Pl. XXIII. f. 12, is one of the most abundant Bivalves in the Wenlock and Ludlow Shales (see p. 127). On the Continent it is also found in Upper Silurian strata, but does not extend its range upward into the Devonian rocks. Cardiola fibrosa, f. 11, is a Lower Ludlow fossil, and C. striata (Cardium, 'Sil. Syst.'), f. 13, is also to be referred to the same genus.

The shells related to Nucula and Arca, in which the hinge-line is beset with close-ranged teeth, are very numerous in individuals, though of few species in the Upper Silurian. Some of them may be true Nuculæ, or even belong to the genus Leda, Forbes; others will fall (see p. 196) into the genus Ctenodonta *, a name proposed in 1851 for those Palæozoic Nuculæ with an external ligament. Ctenodonta Anglica, d'Orb., Pl. XXIII. f. 10, Arca ? primitiva, Phill., Ctenodonta Edmondiæformis, M'Coy, and Ctenodonta subæqualis, Pl. X. f. 7, are Upper Ludlow shells, though most of them had an earlier origin, whilst Ctenodonta sulcata, His. (Mem. Geol. Surv. vol. ii. p. 269), ranges throughout the Upper Silurian. The genus Cucullella, distinguished by a strong internal ridge, contains several Ludlow species. C. antiqua, Pl. XXXIV. f. 16, C. Cawdori, f. 3, and especially C. ovata, f. 17, are common shells in the Uppermost Ludlow (Tilestones, 'Sil. Syst.'). C. coarctata, Phillips, is found in great plenty in the Ludlow rocks of Pembrokeshire, and occurs also in the Wenlock Shale. The genus Cleidophorus, which has no teeth in the hinge, is otherwise much like Cucullella. Cl. planulatus, Conrad, is found, according to M'Coy, in the Wenlock Shale.

Lyrodesma (Actinodonta) cuneata, Phill., seems to connect these Arca-like shells with the Mytilidæ or Mussel family. Lyrodesma is found by hundreds in the shales of Marloes Bay—not, however, in the Upper Silurian, as formerly supposed ('Memoirs of the Geol. Survey,' vol. ii.), but in the Llandovery rocks.

Lastly, as a representative of the Cardiaceæ, we have one small species of Pleurorhynchus, a genus which, as we have before seen, p. 196, commenced existence in the Lower Silurian. Pl. æquicostatus, Phillips, Foss. 60. f. 1, is a miniature example of it, found at Wenlock and Woolhope. In North America, larger species of this genus occur in Upper Silurian rocks.

Lamellibranchiate Shells are far more frequently met with in the Upper Silurian strata than in the Lower—a fact indicated long ago by the organic remains figured in my former work, and confirmed by subsequent observations. Out of forty-five species quoted in Prof. Phillips's memoir †, published nine years after the 'Silurian System,' five or six only are found in the Caradoc Sandstone and Llandeilo Flags. Prof. M'Coy, in his Descr. Pal. Foss. of the Woodwardian Museum, enumerates twenty-three species as belonging to the lower group, while he describes fifty from the Upper Silurian, as many as twelve being common to both divisions. Portlock, indeed, described many Lower Silurian forms of this group from Ireland; but an inspection of the Museum of the Geological Survey, and of numerous private collections, will convince any one that the

* Rep. Brit. Assoc. 1851, Trans. Sect. p. 63. Tellinomya of Hall proves to be the same genus, though the name is not applicable. See his Descriptions of New Palæozoic Fossils, Albany, 1857, p. 141.

† Mem. Geol. Surv. vol. ii. pt. 2, 1848.

larger proportion in species is still on the side of the Upper Silurian rocks; whilst the individuals in them are unquestionably more numerous.

The suggestive remark of Prof. Phillips must here be noticed, that the families to which the Silurian Lamellibranchiata generally belong are those which occur at the junction, so to speak, of the Monomyarian and Dimyarian groups. Mytiloid, Nuculoid, and Aviculoid shells, therefore, with few additions, were the representatives of this order in the Silurian seas.

Gasteropodous Mollusks, or Univalve Shells, are spread throughout the Upper Silurian, but seldom form a conspicuous feature. The Wenlock limestone, however, is neither poor in species nor individuals, though several are yet unpublished. Among them Euomphalus occupies a marked place, four species especially swarming in certain localities, viz. Eu. discors, Sow., Pl. XXIV. f. 12, Eu. rugosus, Sow., f. 13, Eu. funatus, Sow., Pl. XXV. f. 3, and Eu. alatus, His., f. 4. A species also very like Eu. centrifugus, Wahl., not unfrequently occurs with them. Euomphalus sculptus, Sow., f. 2, which appears to be only a variety of Eu. funatus, Sow., is found as frequently in the Llandovery as in Wenlock rocks. Eu. alatus, His., f. 4, is chiefly a Wenlock Shale species, and occurs of the largest size in the calcareous slates of the Dingle promontory in Ireland. It is there associated with several other species, particularly the large Eu. lautus, M'Coy, Eu. carinatus, Sow., Pl. XXIV. f. 11, and Trochonema (Eu.) tricinctus, M'Coy, the second of which is most characteristic of the Middle Ludlow or Aymestry rock. Of all these species, Eu. funatus, Sow., is by far the most common, and has the greatest vertical range. Its concentric operculum is often met with, and helps to show the near relation of the genus to Delphinula, as above stated (p. 196, Note).

Eunema cirrhosa, Pl. XXIV. f. 10, often occurs in the Wenlock Shale; and Platychisma Williamsii, Pl. XXXIV. f. 13, together with some allied species, is frequent in the Upper Ludlow. The Tilestone is crowded with Platychisma helicites, Pl. XXXIV. f. 12, 13, a shell which used to be known as a 'Trochus,' and looks like a land-snail in outward form. Trochus? cælatulus, M'Coy, is a rare species from the Woolhope Limestone; and Cyclonema undifera, M'Coy, is a small species of the Aymestry rock.

The Turritellæ, 'Sil. Syst.,' of the uppermost Ludlow rocks have been already referred to the genus Holopella, p. 196,—H. obsoleta, Sow., Pl. XXXIV. f. 11, H. gregaria, Sow., f. 10 *a*, and H. conica, Sow., f. 10, being very frequent fossils in this stratum in Westmoreland, Shropshire, and South Wales. Prof. M'Coy has distinguished another small species, H. gracilior, from the Wenlock Shale of Llangollen. Loxonema sinuosa, Sow., Pl. XXIV. f. 3, and L. elegans, M'Coy, are chiefly Ludlow rock species. The latter is a fine shell, two inches long, and is frequent both in the Wenlock and Ludlow shales.

Spiral Shells with notched apertures, Pleurotomaria and Murchisonia, are common. Murchisonia corallii, Sow., Pl. XXIV. f. 7, M. articulata, Sow., f. 2, and M. torquata, M'Coy, are slender turreted forms in the Ludlow rocks. M. cingulata, His., three inches long, from Aymestry, is found also in Gothland. M. Lloydii, Sow., Pl. XXIV. f. 5, abounds in the Middle and Lower Ludlow, and is frequent in Wenlock Limestone. Murchisonia balteata, Phillips (Mem. Geol. Surv. vol. ii. pt. 1. pl. 15), is another interesting Wenlock form. Pleurotomaria undata, Pl. XXIV. f. 6, is from the Lower Ludlow, where some other large species, yet unpublished, are also found. Acroculia Haliotis, Pl. XXIV. f. 9, and A. prototypa, f. 8, are exceedingly abundant, the first especially, in the Wenlock Limestone, and also in the Upper Silurian of Bohemia. These mollusks seem

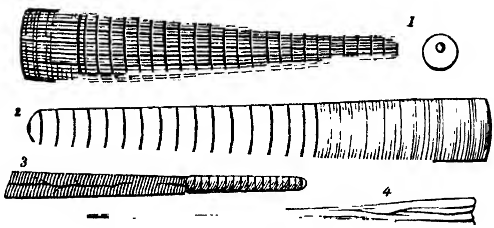
to have formed the chief diet of numerous Encrinites of the period, both in England and America (see p. 223). Natica? parva, Pl. XXV. f. 1, and a few other shells, complete the list of published species; but many others, I am assured by Mr. Salter, remain to be described.

One or two Pteropods only have yet been detected; nor do they seem to be so plentiful as in the lower rocks. Theca Forbesi of Sharpe, a species very like that figured in Foss. 41. f. 1. p. 199, and Th. anceps, Salter, are Wenlock Shale species, and the former is also common in the Upper Wenlock rock. Besides these, Conularia seems to be the only British Upper Silurian Pteropod, unless Ecculiomphalus lævis, Sow., Pl. XXV. f. 9, may be considered a member of this group. The beautiful and variable Conularia Sowerbyi, Defr. (C. quadrisulcata, var., Sil. Syst.), Pl. XXV. f. 10, is often found in Wenlock Limestone, and occurs with a rarer species, C. subtilis, Salter, in the Ludlow rocks of Westmoreland.

Bellerophons are frequent. Bellerophon dilatatus, Sow., Pl. XXV. f. 5, 6, is one of the largest Nucleobranchs in the Ludlow and Wenlock rocks. The broad, expanded mouth is often three inches wide, and is sometimes furnished with radiating ribs (see fig. 5),—at other times smooth, Foss. 41. f. 8, p. 199. B. Wenlockensis, Sow., Pl. XXV. f. 7, is very characteristic of the strata implied in its name. B. expansus, Sow., f. 8, is equally so of the Upper Ludlow rock. The latter and B. Murchisoni?, d'Orb., Pl. XXXIV. f. 19, B. carinatus, Sow., f. 8, and B. trilobatus, Sow., f. 9, generally of small size, are most abundant everywhere in the Upper Ludlow rock.

Of the Cephalopods which chiefly typify the Upper Silurian strata, it is unnecessary to repeat what has been said in describing the Wenlock and Ludlow formations; the species which most abound have already been enumerated (see pp. 114, 127, &c.). It may, however, be noted that some of these forms are specially characteristic of particular strata. Thus the thin-shelled species of Orthoceras—O. subundulatum, Portl., and O. primævum, Forbes, here figured, are the most frequent shells of Wenlock Shale; O. annulatum, Pl. XXVI. f. 1, and its variety, fimbriatum, f. 2, is a well-known Wenlock Limestone species;

FOSSILS (62). UPPER SILURIAN CEPHALOPODA.



1. Orthoceras filosum, Sow. 2. O. Ludense, Sow. These species are figured from specimens two feet in length. 3. O. subundulatum, Portlock (Creseis Sedgwicki, Forbes). 4. O. primævum, Forbes. The two latter are usually 8 or 9 inches long.

O. filosum, Pl. XXVII. f. 1 (Foss. 62. f. 1), O.? perelegans, Pl. XXIX. f. 5, 6, and O. dimidiatum, Pl. XXVIII. f. 5, are common Lower Ludlow fossils; O. Mocktreense, Pl. XXIX. f. 2, is a Middle Ludlow or Aymestry species; while O. Ludense, Foss. 62. f. 2, and Pl. XXVIII. f. 1, O. angulatum, f. 4, O. ibex, Pl. XXIX. f. 3, and especially O. bullatum, f. 1, are frequent Upper Ludlow forms.

Actinoceras nummularium, Pl. XXVI. f. 5, Orthoceras excentricum, Pl. XXVII.

f. 3, O. canaliculatum, Pl XXVIII. f. 3, are rarer Wenlock species; whilst O. distans, Pl. XXVI. f. 4, O. subgregarium, Pl. XXVII. f. 2, and O. imbricatum, Pl. XXIX. f. 7, are among the less abundant Ludlow fossils.

Orthoceras tracheale, Pl. XXXIV. f. 6, and O. (Tretoceras?) semipartitum, f. 5, though not very common, are characteristic of the uppermost Ludlow or Tilestones,—as well as O. bullatum, above noticed, which occurs in the greatest abundance in every locality of the Upper Ludlow rock.

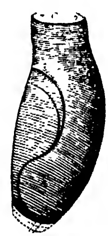
The same distribution is observable in the other genera; for while certain species of Phragmoceras and Lituites are peculiar to the Wenlock, or the Lower Ludlow, but few range throughout. Phragmoceras ventricosum *, Pl. XXXII., however, which has been already mentioned, is one of these last: it is frequently found at Malvern, in Wenlock limestone, and also at Leintwardine, Shropshire, in Lower Ludlow, where also Ph. pyriforme, Pl. XXX. f. 1–3, abounds. This species, being straight instead of curved, has usually been regarded as a distinct genus, Gomphoceras. Phragmoceras arcuatum, Pl. XXXI. f. 3, and Ph. intermedium, Pl. XXX. f. 4, are also Lower Ludlow forms. Ph. nautileum, Pl. XXXI. f. 1, 2, and Ph. compressum, f. 4, are found in Wenlock shale; the last is even a Llandovery fossil.

Lituites articulatus, Sow., is found both in Wenlock and Ludlow rocks; L. Biddulphii, Pl. XXXI. f. 5, in Wenlock limestone. Lituites giganteus, Pl. XXXIII. f. 1, 2, 3, is one of the finest fossils from Leintwardine and Malvern; and L. tortuosus, of which a fragment is figured, f. 4, is found in the black nodules of the Wenlock Shale near Welshpool, and also at Dudley.

The curious genus Ascoceras, of which Barrande has described several species from the Bohemian basin, has been found in the uppermost Silurian rocks of Britain. The species differs but little from the common Bohemian form; it has been called A. Barrandii by Mr. Salter. There are specimens from Usk, Ludlow, and Malvern in the Museum of Practical Geology; and it may prove to be common. This fossil seems more nearly allied to the curious genus Tretoceras above mentioned (p. 213: Diploceras in the former edition) than might be at first supposed.

FOSSILS (63).

AN UPPER LUDLOW CEPHALOPOD.



Ascoceras Barrandii, Salter (Quart. Journ. Geol. Soc. 1856, vol. xii. p. 381). From near Usk, Monmouthshire, in Upper Ludlow rock.

To complete the catalogue of the Upper Silurian fauna, a brief sketch must be given of its Annulose animals, the Worms and Crustaceans, as well as of the remains of Fishes which have been discovered.

Cornulites serpularius (see Pl. XVI. f. 3–10) is still, as in the Llandovery rocks, the principal Annelide, and, though more frequent in the Wenlock Limestone, is not rare in the Ludlow rocks. The finest specimens are from the Wenlock Limestone of Ledbury; but at Dudley, Cornulites are found attached to shells, in groups of three or four together, like Serpulæ; and they occur in profusion on the hard and sea-worn surfaces of the Ludlow rock at Marloes Bay in Pembrokeshire, in masses a foot in diameter. Tentaculites ornatus, Pl. XVI. f. 11, abounds in the Dudley limestone; whilst a small species, T. tenuis, f. 12, occurs in the Upper Ludlow rock. The place of the latter is sometimes taken

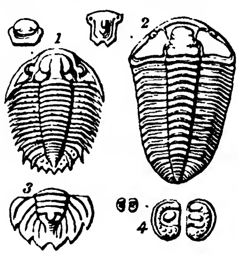
* [This fine Silurian species can scarcely be the Orthoceras ventricosum of Steininger.—J. W. S. 1859.]

by a form so like T. Anglicus, Salter, of the lower division, that it may possibly be a variety only, in which case we gain another characteristic fossil for uniting the two groups. This Tentaculite is plentiful, like the Cornulite, in the sandy Ludlow rocks of Marloes Bay and Freshwater, Pembrokeshire.

Other Annelides (Serpulites, Sil. Syst.) are very common in the Ludlow rock. They are flattened tubes, thick at each projecting edge, sometimes shelly, but at other times corneous, or even membranous on the sides. Serpulites longissimus, Pl. XVI. f. 1, grew to a length of twenty inches, measured along its spiral curve. It is one of the type fossils which most attracted me when I first traced the range of the Upper Ludlow rock. Greyish-blue portions of it are found in that band over great distances throughout the Silurian region, and the small shining fragments are often mistaken for remains of Fish. Serpulites dispar, Salter, from Kendal, the tube of which has remarkably thin sides, is figured in the work descriptive of the Woodwardian Museum. Trachyderma coriaceum and T. squamosum of Phillips* are wrinkled tubes of these Annelides, frequent in the Ludlow rocks of the original Silurian region, and are occasionally found in an upright position in the bed. A few other species are found in the Wenlock strata and the stratum which I formerly distinguished as the Fucoid-bed of Ludlow (p. 133). It appears to contain no remains of Sea-weed, but to be made up of the closely interwoven burrows of marine Worms, and perhaps Crustaceans.

The chief Crustacea are Trilobites. They are exceedingly abundant, forming in some beds, and especially in the Wenlock Limestone, the most conspicuous fossils. Many forms have been already quoted in the preceding Chapters; and two woodcuts are here given, to represent either the principal forms not illustrated in my original work or those now more perfectly known. Among the latter we may reckon the elegant and highly ornamented Dudley fossils, En-

FOSSILS (64). UPPER SILURIAN CRUSTACEA.



1. Lichas Anglicus, Beyrich; and its hypostome or labrum. 2. Calymene tuberculosa, Salter; also with its labrum. 3. Lichas Barrandii, Fletcher. 4. Beyrichia Klœdeni, M'Coy; natural size and magnified. The other figures are reduced to about half size.

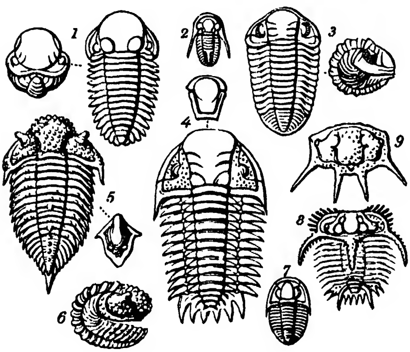
crinurus punctatus, Foss. 65. f. 5, and E. variolaris, f. 6. These, which are known by the name 'strawberry-headed' by collectors, are found on every slab of Wenlock limestone, but seldom perfect except at Dudley, whence the fine specimens formerly in the cabinets of Mr. Gray and Mr. Fletcher were obtained. Cheirurus bimucronatus, Foss. 65. f. 4, figured from fragments only in Sil. Syst., is found perfect in the same collections, and in the cabinet of my friend the Rev. T. T. Lewis. The singular genus Acidaspis is now better understood than when I formerly described it; and no less than six species of this genus, besides Acidaspis Brightii (Pl. XVIII. f. 7, and Foss. 65. f. 8), are known in the Upper Silurian rocks. The head, Foss. 65. f. 9, of one of the largest species, called A. Barrandii by Mr. Fletcher, is here figured. It belongs to a group

* Mem. Geol. Surv. vol. ii. part 1. pl. 4.

remarkable for having the lobes of the head nearly obliterated, and possessing two large neck-spines. The common Calymene Blumenbachii, Pl. XVIII. f. 10, was perhaps the most prolific of all the Silurian Trilobites, and is, as before stated, known also in the lower division of the system. C. tuberculosa, Pl. XVIII. f. 11, and Foss. 64. f. 2, which was formerly given as a variety of it, is a very plentiful species in the Wenlock Shale.

Among the Trilobites here figured which were not published in my former work, Sphærexochus mirus, Foss. 65. f. 1, is singularly formed, the head being so inflated as to resemble a ball. This Wenlock fossil has a very general geographical or horizontal range, being found both in America and Bohemia in Upper Silurian rocks. It appears, however, to have existed earlier in Britain than in those distant parts; for it is found in the equivalent of the Caradoc rocks in Ireland. Four or five species of Lichas (a genus already figured in Chap. IX.) are now known in Wenlock Limestone. The genus is remarkable for the shape of the head and its lobes. L. Grayii, L. Salteri, L. Barrandii, Foss. 64. f. 3, and L. hirsutus are all species figured and named by Messrs. Fletcher and Salter from Mr. Fletcher's rich collection (Quart. Journ. Geol. Soc. vol. vi. p. 235). With

FOSSILS (65). WENLOCK LIMESTONE TRILOBITES.



1. Sphærexochus mirus, Beyrich; with a coiled-up specimen. 2. Cyphaspis megalops, M'Coy. 3. Phacops Downingiæ, Murch.; both extended and coiled-up. 4. Cheirurus bimucronatus; and its labrum or lip. 5. Encrinurus punctatus, Brün.; and its labrum; drawn from a Dudley specimen. 6. E. variolaris, Brong. 7, Proetus latifrons, M'Coy. 8. Acidaspis Brightii, Murch. 9. A. Barrandii, Fletcher and Salter; the head or cephalothorax.

them is associated a small and very common species, the L. (Arges) Anglicus of Beyrich, Foss. 64. f. 1, of which a very imperfect illustration was formerly given in Brongniart's work, from a Dudley specimen. It occurs also in Upper Ludlow rock, in the Whitcliffe, Ludlow. Phacops Downingiæ (Foss. 65. f. 3, and Pl. XVIII. f. 2–5), and P. caudatus, Pl. XVIII. f. 1, with its variety, P. longicaudatus, Pl. XVII. f. 3–6, have been already quoted (p. 121) as very common forms.

Proetus Stokesii, Pl. XVII. f. 7, and P. latifrons, Foss. 65. f. 7, are also far from rare in Wenlock strata. Bumastus Barriensis, Murch. (Illænus, auct.), Foss. 17. p. 111, and Pl. XVII. f. 9–11, ranges, as before said, from the lowest Wenlock beds to near the top of the Upper Silurian. This fine fossil occurs of the largest size in the Woolhope Limestone, and is found in the pipeclay beds of that formation at Malvern. Two species of Homalonotus also have been already quoted, pp. 111, 133; H. Knightii, König, being very characteristic of the Upper Ludlow rock.

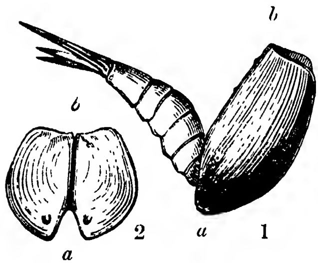
Cyphaspis megalops, M'Coy, Foss. 65. f. 2, and a small species, C. pygmæus, Salter, are the only species of that genus known in England. The former began life in the Lower Silurian epoch. Deiphon Forbesii, Barrande, is a rare, globular-

headed Trilobite, found both in the Dudley limestone and its equivalent rock in Bohemia. And, lastly, there is a species of Bronteus, probably Br. laticauda, Wahlenberg, found by my deceased friend Dr. Lloyd, in the Wenlock Limestone. It is figured by Professor Phillips under the name of Br. signatus (Palæoz. Foss. of Cornwall, &c., f. 254). The original of this rare fossil is in the cabinet of Professor Tennant, of London.

A goodly list of Trilobites of the Upper Silurian rocks has thus been given; and many other forms will probably reward research.

The small Bivalve Crustaceans, such as Beyrichia, M'Coy, Leperditia, Rouault, and Primitia, Jones, remain to be noticed. They are very numerous. The most abundant Upper Silurian species is Beyrichia Klœdeni, M'Coy, Foss. 64. f. 4, according to Professor T. Rupert Jones, our best authority on these subjects. It is a very abundant species from the base of the Wenlock Shale to the highest Ludlow stratum, varies greatly in shape, but is a good index of the Upper Silurian, though found sometimes in the Llandovery rocks. B. Wilckensiana, Jones, is also plentiful in the Ludlow rocks, and B. siliqua, Jones, has been detected in slabs of Woolhope Shale near Malvern. The Lower Silurian form, it will be recollected, is B. complicata, Salter (pp. 204, 205). Dr. H. B. Holl has found many of these Bivalve Crustacea well preserved in the Upper Silurian limestones near Malvern; they are numerous and of a still finer growth in the Upper Silurian limestones of Gothland. The Beyrichiæ, together with the little Primitiæ, and the relatively large Leperditiæ of Gothland, are, in the opinion of good naturalists, probably of the Phyllopod tribe, and more nearly allied to living forms than the Trilobites that accompany them.

FOSSILS (66). UPPER SILURIAN CRUSTACEANS.



Ceratiocaris from Lesmahago—f. 1, with its abdomen displaced and recurved*; and f. 2, the carapace of another species, showing the two valves of which it is composed. *a.* Anterior, *b.* posterior end of carapace.

So also may be some larger, shrimp-like forms, Ceratiocaris, from the Ludlow rocks of Ludlow, Kendal, and the South of Scotland. One of these, C. inornatus, M'Coy, is three or four inches long. The carapace, or front part only of the body, of this species, was described by Professor M'Coy; but the possession of more perfect specimens of other species—some even of greater size—has now permitted the delineation of the entire form. There appears to be good evidence that Ceratiocaris was a Bivalve Crustacean, probably of the Phyllopod tribe. To the same genus also belong those curious striated crustacean spines which are represented in Pl. XIX. f. 1, 2. They were skilfully distinguished, by

* This position of the body at first misled observers as to which was the front and which the hinder end of the Carapace; but the position of the ocular tubercles pointed to the anterior part of the carapace; and the question has been definitively solved by the help of a specimen obtained by Mr. Slimon from Lesmahago and now in the British Museum, in which the maxillæ are seen within the anterior portion of the carapace, apparently *in situ*. (See Mr. H. Woodward's paper on Crustacean Teeth, in the 'Geological Magazine,' 1865, vol. ii. p. 401, pl. 11. fig. 1.)

Prof. M'Coy, from fish-defences, with which they were formerly confounded. (See p. 134.) That naturalist, indeed, supposed them to be the slender pincers of some large Crustacean, and hence called them Leptocheles, viz. L. (Ceratiocaris) leptodactylus (from the Lower Ludlow) and L. (C.) Murchisoni, Pl. XIX. f. 1; but M. Barrande had, at the same time, found more perfect specimens in Bohemia, indicating that these long-pointed spines formed the trifid tail of a Crustacean, something like that of the Carboniferous genus Dithyrocaris. His accurate figures, as yet unpublished, show, however, only the terminal segment of the abdomen. The perfect specimens from Ludlow and Lesmahago show the entire structure; and we are now, therefore, able to unite all these forms in one genus. There cannot be less than twelve or fourteen species distributed in the Lower and Upper Ludlow rocks: some of them must have been nearly a foot in length, and others are minute *.

The largest, if not the most highly organized, Crustacean in the Silurian list is the Pterygotus problematicus, Agas., before mentioned. The fragments of the body-rings, which are represented, Pl. XIX. f. 4, 5, were at first considered by Agassiz to be fish-scales †; but that author soon afterwards corrected his statement ‡, and assigned the animal its true place among the Crustacea. Reference has already been made to several other species, pp. 126, 140, the most gigantic of which, perhaps, occurs in the Tilestone quarries of Kington. The dimensions which Pt. problematicus (the Ludlow species) attained are unknown,—though, from fragments of the pincers described by Strickland and Salter §, it was probably not much smaller than the great Scotch Pterygotus, the 'Seraphim' of the Scottish quarrymen, which must have been 5 or 6 feet in length ‖. Prof. M'Coy first referred Pterygotus to the Pœcilopoda (Limulus &c.); Mr. Henry Woodward has united the Eurypterida and Xiphosura in one order (Merostomata, of Dana) ¶, of which the large King-crab (Limulus) is the modern type; and Professor James Hall has beautifully figured many complete specimens of Eurypterus from Buffalo, Lake Erie **. D'Eichwald's and Professor Nieszkowski's †† figures of the Russian Eurypteri (see p. 162) are also very good; and now that the entire form of Pterygotus itself has been discovered, they help to complete the evidence for the formation of a new suborder of Crustacea. These are the Eurypterida—already so named by Burmeister, but with a meaning different from that which the term now implies.

In a memoir already quoted (Quart. Journ. Geol. Soc. vol. xii. p. 28), Professor Huxley has given reasons for considering these large Crustacea to be of a type nearly resembling some of the smallest of our living Decapod Crustacea (Alauna, Bodotria, Cuma, &c.), and as even showing great similarity to the larval state of the higher forms; and he adopts the term Eurypterida as including these two Palæozoic genera (Pterygotus and Eurypterus), if not some others also, at present unsatisfactorily arranged among the Phyllopods ‡‡.

The entire form of Pterygotus was very simple (Foss. 26, p. 162):—a small, half-oval, or subquadrate carapace, followed by thirteen convex body-rings, the last of which formed a pointed, truncate, or even bilobed tail-joint; two large, compound eyes on the sides of the carapace; and beneath it the mouth is situated, protected by a large heart-shaped labrum.

* See Geol. Mag. vol. iii. p. 203, pl. 10. figs. 8–10.

† Sil. Syst. p. 606.

‡ Poiss. Vieux Grès Rouge, pl. 1.

§ Quart. Journ. Geol. Soc. (1852) vol. viii. p. 386, pl. 21.

‖ Pterygotus (Himantopterus) Banksii could not have measured as many inches.

¶ Monograph, Palæont. Soc. 1866.

** Palæont. New York, vol. iii. 1859, pp. 382, 419*, and plates.

†† Archiv Natur. Liv-, Esth- und Kurl. 1859, 1st ser. vol. ii. p. 299, pls. 1 & 2.

‡‡ See the Memoir on these Palæozoic Crustacea by Huxley and Salter, Monograph I., Memoirs Geological Survey of Great Britain, 1859.

Five pairs of mouth-appendages are known:—a pair of large 6–7-jointed antennæ with massive chelæ, which are furnished with sharp cutting teeth, large and small; three pairs of mandibles with serrate edges, and with a single palpus of 6 or 7 joints. Then there is the large pair of swimming-feet of seven joints each, the basal joint excessively large and serrate at its inner edge, and the terminal joints expanded for swimming, like those of the pelagic crabs (Polybius, &c.).

These are all attached to the carapace. No appendages to the rings of the body have been observed; but attached to the posterior border of the head-shield on the lower side, and covering the under surface of the first and second anterior segments, there is seen a broad thoracic plate, apparently homologous with the opercular plate in Limulus, which covered, no doubt, in the fossil, as in the recent Crustacean, the reproductive organs and the branchiæ. There appears to be good evidence that one or more plates, similar in form, lie concealed beneath this opercular plate, as in the recent King-crabs. This point of structure has been independently noticed by Professor Hall in North America, Professor Nieszkowski in the Baltic Provinces, and by Messrs. Salter and H. Woodward in this country. (See the Monograph on the Merostomata, Pal. Soc. 1866.)

Eurypterus, though resembling Pterygotus, differs from it in having the eyes within the cephalic shield, not upon the border,—also by the want of the great pincer-like claws, as we find by the figures given by Professor Hall (*op. cit.*). Eight species of the genus have been found in Britain; and they have similar scale-like sculpturing, though less conspicuous than in Pterygotus.

The distribution of these two genera is as follows:—

As already stated, p. 96, there is a rare species of Pterygotus in the Upper Llandovery rocks, and fragments of a Pterygotus occur in the Wenlock beds, though it is only of late that any forms of the genus have been found in so old a rock even as the Lower Ludlow, in which two species occur: the chief one, distinguished by its prominent and pointed squamæ, and by its long swimming-feet, has been called Pt. punctatus by Mr. Salter; its mandibles are furnished with large fringed palpi. The other species has more open sculpture, like that of the Pt. problematicus, Agas., which is characteristic of the Upper Ludlow rock. Of this latter species, mere fragments are yet known, including parts of the feet, the jaws, the antennæ (described as pincers, see p. 237), and some portions of the underside. There are, however, at least two large and several small species in the Upper Ludlow rock.

Again, from the Tilestones of Kington, Herefordshire, Mr. Banks has disinterred another fine Pterygotus, which has a wide expanded precaudal joint and a head rounded in front. This is not the same species as the large fossil already described under the name Pterygotus Anglicus, Agas.; and, as it appears not to be identical with Pt. problematicus of Agassiz, it has been named by Salter Pt. gigas *. This must have been truly a gigantic form, rivalling if not exceeding in size the nearly allied Pt. Ludensis, already referred to in Chap. VII.

* Geol. Surv. Mem., Monograph, No. I. 1859. In justice to Mr. R. W. Banks, of Kington, I must here state that he had long collected materials for the illustration of Pterygotus gigas, and had been fortunate enough to discover a great number of parts, which he succinctly described in the Quart. Journ. Geol. Soc. vol. xii. p. 97. On the publication, however, of the more complete specimens from Lanarkshire, he liberally made over his materials for description in the Geological Survey Memoirs, Monograph No. I.

Pterygotus Ludensis, so abundant at Ludlow and Kidderminster in the 'Passage-beds,' has the greatest analogy with the Scotch fossil, Pt. Anglicus, which occurs in the lowest part of the Old Red Sandstone of Scotland. Pt. pro-

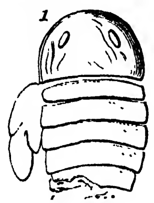
As tending to indicate an exact horizon for some of these species, it may be remarked that Pterygotus gigas, Salter, is now known to occur just at the junction of the Silurian and Old Red formations at Kington; whilst in beds a little higher, at Ludlow and at Kidderminster, the Pt. Ludensis, Salter, is the prevailing fossil. There is reason to believe that the beds in Forfarshire, in which the great Pterygotus Anglicus, its closest ally, is found, are of the same date.

Both in Scotland and in Worcestershire Pterygotus is accompanied by Parka decipiens (see Chap. XI.), a fossil which Dr. J. Fleming supposed to be the fruit (or receptacle of the fruit) of some plant. There is strong reason for believing that these fossils are, on the contrary, the egg-packets of Pterygotus. They are of a discoid shape, and puckered and plaited from the point of attachment as from a centre. The appearance is as if a tough membrane containing rounded and rather soft egg-shaped bodies had suffered compression in the rock. The ovoid masses afford no indications of a style or stigma, such as must have been present had they been of the nature that Dr. Fleming supposed. That a great Crustacean, so like in many respects to the Copepoda, should have had large ovisacs, or that it deposited large masses of ova, on such aquatic vegetation as that noticed by Mr. Powrie in the same beds in Forfarshire, is far from unlikely, although the discoid shape of the fossil bodies * is different from that of the living forms.

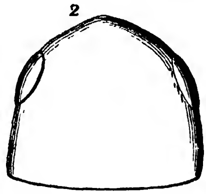
There are indications of several other species of Pterygotus in the Tilestones: Pt. Banksii, the least of them all, is here figured, Foss. 67. f. 2.

FOSSILS (67).

PTERYGOTUS AND EURYPTERUS, FROM THE TILESTONES OF KINGTON.



1. Eurypterus pygmæus, Salter.



2. Pterygotus Banksii, Salter.

As far as has yet been ascertained, the genus Pterygotus preceded Eurypterus in time, the oldest Eurypterus yet found being E. cephalaspis †, Salter, from the Upper Ludlow rocks of Westmoreland; but it seems to have continued longer in existence. E. pygmæus, Salter, Foss. 67. f. 1, a small and abundant species in the Tilestones at Kington and Ludlow, accompanies other species at the latter place. The genus occurs in beds of the same age in Russia, as already noted (p. 162). And, as we shall afterwards see, a fine species (or two) is

blematicus, on the contrary, which commences in the Upper Ludlow rock, appears to range up into the Cornstones, having been found by Dr. John Harley, of King's College, in those beds at Hopton Gate, Ludlow. This is the highest range of the genus known, and corresponds with the great extent to which the supposed egg-packets of this Crustacean (Parka decipiens) are found in the Lower Old Red Sandstone of Forfarshire, — Tealing, near Dundee, and Carmylie, near Montrose, being localities rich in Pterygoti.

* Dr. Mantell suggested that these were ova of Batrachians (Quart. Journ. Geol. Soc. vol. viii. p. 106; see also Lyell's Manual, 5th edit., p. 421); and Mr. D. Page has remarked, that not only are some of them probably of vegetable origin, as described by Dr. Fleming, but others are possibly the spawn of Batrachians and Mollusks, and even of the Crustaceans so common in the Old Red (Advanced Textbook, 1856, p. 127). See also Geol. Surv. Mem., Monograph I. p. 77.

† Appendix to Pal. Foss. Woodw. Mus. pl. I E. fig. 21.

found in the Old Red Sandstone, and also in the lower beds of the Carboniferous rocks of Scotland, whence they were first described by Dr. Hibbert *.

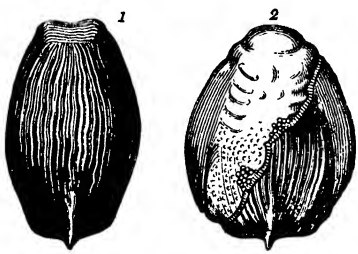
Mr. Henry Woodward has of late enriched the list of Silurian organic remains by recognizing the existence of Cirripedes among the fossils of the Wenlock Limestone of Dudley, De Koninck's Chiton Wrightianus having proved to be really a new form of this suborder. Several specimens have been found. It is the earliest known of the pedunculated Cirripedes, and has been named Turrilepas by Mr. Woodward †.

In the first edition it was affirmed that in the true Bone-bed of Ludlow no remains of Fish, save those of a few placoid genera, were to be met with. Even here their remains are very scanty, some of those few which were formerly referred to the class having been removed, as stated at p. 134, to Crustaceans. But those remarkable heads called Pteraspis (Pl. XXXVII. f. 9–11) are still to be referred to Fishes, according to Professor Huxley, who has ascertained that there is no essential difference between their structure and that of Cephalaspis ‡. There are at least two species of these old anomalous Ganoid? fishes in the Ludlow rock itself. Both have been found near Ludlow,—one in the grey Ludlow rock, by Dr. John Harley, of King's College, London; the other, by Mr. A. Marston, in the Bone-bed of Ludlow.

The first of these, which is of a plain oval form, and with only fine longitudinal striæ, is probably P. truncatus, Huxley and Salter, Foss. 68. f. 1; the other, a broader species, is P. Banksii, ib. f. 2. Both of these (here figured)

FOSSILS (68).

FISHES (PTERASPIS) FROM THE LUDLOW ROCK AND PASSAGE-BEDS §.



1. Pteraspis truncatus, Huxley and Salter, from the 'Passage-beds,' Kington. 2. P. Banksii. Huxley and Salter; an ornamented species, showing, too, the cervical spine. From Upper Ludlow rock at Ludlow: the same species occurs in the 'Passage-beds.'

were discovered by Mr. Banks in the 'Passage-beds' of Kington in Herefordshire (p. 138); the latter species was also found near Kidderminster by the late Mr. George Roberts, together with the Pterygotus before mentioned. The two species of Cephalaspis in the shale at the Ludlow Railway-Station (p. 139) must not be forgotten. The occurrence in true Ludlow strata of one, if not two,

* Trans. Roy. Soc. Edinb., 1st ser., vol. xiii. pl. 12.

† Quart. Journ. Geol. Soc. vol. xxi. p. 486.

‡ Mr. E. R. Lankester's description of the scales of Pteraspis, and of the shape of the perfect head-shield, forms a valuable contribution to our knowledge of this interesting Fish. Quart. Journ. Geol. Soc. vol. xx. p. 194.

§ The fish-fragments figured above, as well as those illustrated in Pl. XXXVI. under the name Pteraspis, require a note of explanation as to the name. They received that name from Dr. Kner (see Haidinger's Abhandl. vol. i.) in 1847, who referred them to Cephalopoda. They have since been regarded by some as Crustacea, though Agassiz placed them among Fishes of the genus Cephalaspis.

In a memoir read before the Geological Society (Quart. Journ. vol. xiv. p. 267), Professor Huxley definitely included them in the class of Fishes. I may here observe that my friends the Rev. W. Symonds and the late Rev. F. Dyson, knowing the position in which these Fishes ought to occur, discovered them in their own Malvern district, and have detected the principal species in the Lower Cornstones of the Old Red Sandstone at Cradley.

species of true Fishes identical with those of the 'Passage-beds' is a fact of importance, as tending to connect the latter intimately with the Silurian rocks.

Besides these, however, and in the Ludlow Bone-bed itself, there are remains of other Fishes *—defences of the fins of Shark-like species, with shagreen or skin, jaws and teeth, and other minute fragments less easily determinable.

Onchus tenuistriatus, Pl. XXXV. f. 15–17, and O. Murchisoni, f. 13, 14, are bony fin-spines, such as are possessed by placoid Fishes of the present day. Sphagodus, f. 1, 2, is the prickly skin of some such animal, and may have belonged (as suggested by M'Coy) to one of the former. The small cushion-like bodies, f. 18, called Thelodus parvidens by Agassiz, that occur by myriads in the stratum, often forming large portions of its thin layers, are certainly the granules of the skin, or shagreen, of one or other of these two common species. The remarkable jaws and teeth, Pl. XXXV. f. 3–8, first figured in my former work, and named by Agassiz Plectrodus mirabilis and Pl. (Sclerodus) pustuliferus (f. 9), must still be regarded as the jaws and anchylosed teeth of some small Ganoid fish—possibly even (as suggested by Mr. Salter) of Pteraspis or Cephalaspis, the teeth of these genera, if they had any, being yet unknown. Professor M'Coy, however, is inclined to refer these bodies also to the order of Crustaceans,—an opinion which, from the descriptions of Egerton, is not tenable. Their texture is solid and bony, and retains the jet-like lustre which the other fragments exhibit.

Again, as evidence of the predaceous habits of some of these Fishes, the small coprolitic bodies, Pl. XXXV. f. 21–28 (which, according to Dr. Prout's analysis, contain the due admixture † of phosphate and carbonate of lime, with other matters), retain, imbedded in them, fragments of the various small Mollusks and Crinoids which inhabited the sea-bottom in company with the Fish. It thus appears that Bellerophon, Holopella, Lingula, Discina, and Orthis were all preyed upon by these minute but dominant creatures; and the half-digested Shells remain here, as in the excrement of Fishes of many later formations, and of the present period, to attest the character of their food and the extent of their depredations.

Thirty years have now elapsed since I announced that these Fishes of the Upper Ludlow rock appeared before geologists as the most ancient beings of their class ‡; and indefatigable subsequent researches in the various parts of the world over which Silurian rocks extend have as yet failed to alter this generalization, except that one fragment of a Pteraspis has been found in the lower part of the same Ludlow formation (see p. 126). In other countries, indeed, besides our own; as in America and Bohemia, and notably of late in Russia, Ichthyolites have been discovered just within the pale of the Silurian rocks; but there, as with us, they are found merely on the threshold of the system, and, except in Russia, very

* In a survey of the May Hill district, in Gloucestershire, made whilst the pages of the first edition were passing through the press, Mr. H. E. Strickland and myself, reexamining the cutting of the Gloucester and Ross railroad, near Flaxley (which my friend had already described, Quart. Journ. Geol. Soc. vol. ix. p. 8), discovered two thin bone-beds, each little more than an inch thick, and separated by about fifteen feet of fossiliferous Upper Ludlow rock. On the same occasion we observed that the only remains of small land plants (one of which seemed to be a stem, and the others numerous seeds, termed 'spore-cases of Lycopodiaceæ' by Dr. Hooker, see p. 138) occurred in beds above the uppermost fish-layer, and therefore at the very top of the Ludlow formation, just beneath the lowest beds of the Old Red, in which we found a Cephalaspis,—the two deposits being there conformably juxtaposed. See Chap. VII.

† Sil. Syst. pp. 199, 607.

‡ Sil. Syst. ch. 45, p. 606.

sparingly. We may therefore fairly regard the Silurian system, on the whole, and certainly all the Lower Silurian, as representing a long and early period in which no bony vertebrated animals had been called into existence.

But here we must recollect that, when first created, the Onchus of the uppermost Silurian rock was a marine Fish of high and composite order, and that it exhibits no symptom whatever of transition from a lower to a higher grade of the family, any more than the Crustaceans or the Cephalopods and other Shells of the lowest fossiliferous rocks, all of which offer the same proofs of elaborate organization. Nor does the structure of Pteraspis, which must now be regarded as the earliest known British genus, since it occurs in the Lower Ludlow rock, offer, in Professor Huxley's opinion, any evidence of having occupied a lower position in the scale than existing Ganoid or possibly Siluroid Fishes. In short, the first created Fish, like the first forms of those other orders, was just as marvellously constructed as the last which made its appearance, or is now living in our seas.

In a word, the geologist who stands on the summit of the Silurian rocks of Shropshire and Herefordshire, where they graduate imperceptibly into the Old Red Sandstone, and casts his eye westward over the mountains of Wales, sees before him ancient masses in which, though replete with copious animal remains (the tenants of preexisting shores and deep sea-bottoms), no traces of Vertebrata have ever been detected. Looking eastward, on the contrary, hills of red sandstone appear, the lower strata of which immediately succeed to the fish-beds of the Ludlow rocks; and in those he finds that Fishes are the characteristic fossils.

Examining upwards from that first great *piscina* of by-gone days, the Old Red Sandstone or Devonian, which will be considered in the next Chapter, he ascertains that the superjacent and younger strata, whether Primary, Secondary, or Tertiary, are all characterized by containing Ichthyolites. In other words, the three or four peculiar Fishes just enumerated may be viewed as the heralds which announced the close of the Silurian era in Britain, and the advent of the numerous other families of this class, which thenceforward are found in all the younger sediments. The name 'Silurian' marks, therefore, a vast series of fossiliferous deposits, throughout the great mass of which no remains of vertebrated bony animals have been discovered.

CHAPTER XI.

THE OLD RED SANDSTONE, OR DEVONIAN ROCKS, AS EXHIBITED IN THE BRITISH ISLES.

HAVING described at some length the lowest known receptacles of former beings, a shorter consideration only can be devoted to the younger races which were successively enclosed in the higher tiers of the vast primeval burying-places.

During the accumulation of nearly all the Silurian deposits of Britain, which were characterized by a certain fauna, the bottom of the sea was, to a wide extent, occupied by dark and grey-coloured sediments. At the close of that period a great change occurred over large areas in the nature and colour of the submarine detritus. In and around the Silurian region, for example, the dark-grey mud was succeeded by red silt and sand; the colour being chiefly caused by the diffusion of iron-oxides in the waters *. These physical changes were accompanied by the disappearance of those tenants of the deep, the records of which we have been tracing, and by the appearance of other animals.

The gradual passage upwards, from the highest strata of the grey Silurian rocks into such red deposits of England, Wales, and a part of Scotland, has already been alluded to †, and illustrated by several diagrams.

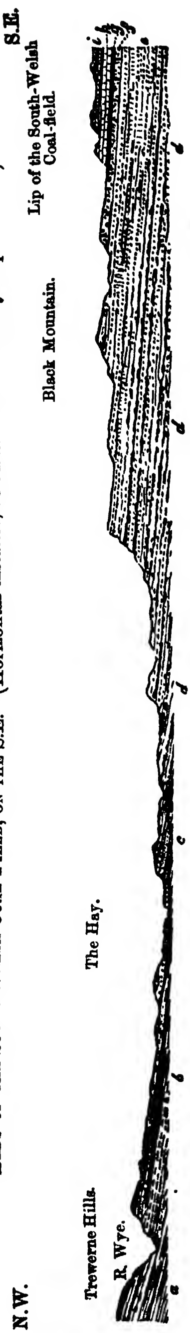
In the lower junction-beds, as seen within the Silurian region, it is only by the detection of certain Upper Ludlow fossils in thin beds or tilestones, partially also of reddish colours, that the limit can be defined, so gradual is the mineral transition from the strata of the one era into those of the other. Still the change is, on the whole, lithologically well marked in that region, from the underlying grey Silurians to the overlying red and yellow rocks.

Good examples of this succession are to be seen near Ludlow, between that town and the Clee Hills, and thence all along the eastern edge of the Upper Silurian rocks in Hereford, Radnor, and Brecon, as well as on the west flank of the Malvern and May Hills, and around the valley of Woolhope. The grandest exhibitions, however, of the Old Red Sandstone in England and Wales appear in the escarpments of the Black Mountain of Herefordshire, and in those of the loftiest mountains of South Wales, the Fans of Brecon and Carmarthen,—the one 2860, the other 2590 feet above the sea. (See Map.) In no other tract of the world, visited by me, have

* See some excellent observations on the influence of iron-oxides on marine life, by the late Sir Henry De la Beche, Mem. Geol. Surv. of Great Britain and Ireland, vol. i. p. 51.

† Pp. 55, 56, 58, 64, 87, 106, 110, 124 & 134–144.

SECTION FROM THE TOP OF THE SILURIAN ROCKS, ON THE N.W. IN MONMOUTHSHIRE, ACROSS THE WHOLE AREA OF THE OLD RED SANDSTONE, TO THE BOTTOM BEDS OF THE SOUTH-WELSH COAL-FIELD, ON THE S.E. (Horizontal distance, 25 miles. From 'Sil. Syst.' pl. 31. f. 1.)



a. Upper Ludlow rock and Tilestones. *b.* Red marls and flagstones. *c.* Whitish sandstones. *d.* Red and green marls, sandstones, and cornstones. *e.* Chocolate-coloured sandstones. *f.* Conglomerate and sandstone forming the summit of the Old Red (in other parts a yellow sandstone). *g.* Lower Limestone-shale. *h.* Carboniferous Limestone. *i.* Millstone-grit. [To save space, the wide and deep valley of the Usk, between the Black Mountain and the lip of the South-Welsh coal-field, is omitted.]

I seen such a mass of red rocks (estimated at a thickness of not less than 10,000 feet) so clearly intercalated between the Silurian and the Carboniferous strata; for, whilst (as represented in the diagram, p. 58) the fore and middle grounds are occupied by Lower and Upper Silurian rocks, described in Chapters III. to VII., the lofty distant mountains are entirely composed of Old Red Sandstone. The observer has only to repair to the southern slopes of those mountains beyond the line of vision in that sketch, and he will there see the uppermost beds of the red rocks conformably overlain by the Carboniferous Limestone of the Great South-Welsh coal-basin. (See annexed diagram.)

If, then, the pictorial sketch given at p. 58 represents the whole region from the Lower Silurian slates to the summit of the Old Red, this diagram, taken from one of the coloured sections of the 'Silurian System,' indicates the copious succession of red strata, which are exposed between the Upper Silurian, *a*, of the Treweme Hills, and the Carboniferous rocks, *g*, *h*, *i*, of the Great South-Welsh coal-field near Abergavenny.

Consisting in its lower parts of red and green shale and flagstone, *b*, with some small 'cornstones' and whitish sandstone, *c*, the central and largest portion of the deposit is composed of spotted green and red clays and marls, *d*, which afford, on decomposition, the soil of the richest tracts of the counties of Brecknock, Monmouth, Hereford, a large portion of Salop (Shropshire), and small parts of Gloucester and Worcester. These argillaceous beds alternate, indeed, with sandstones, occasion-

ally of great thickness. They also contain the greatest quantity of those irregular courses of mottled red and green earthy limestones termed 'Cornstone,' and which, though usually consisting of small concretionary lumps only, expand here and there into large subcrystalline masses, particularly on the western face of the Brown Clee Hills, Shropshire. A higher member of the series is composed of grey, red, chocolate, and yellow-coloured, fine-grained, micaceous sandstones and flagstones, *e*, which, in certain tracts, are surmounted by pebbly beds and conglomerates, *f*, as along the encircling underlying edge of the Great South-Welsh Coal-basin. These last-mentioned rocks are as well exposed in the lofty escarpments of the Fans of Carmarthen and Brecon above alluded to, as in the range of the hills near Abergavenny on the south bank of the River Usk. Similar hard sandstones and conglomerates constitute, in like manner, a symmetrical girdle around the coal-basin of the Forest of Dean, Gloucestershire (see Map), where, and in the gorges of the Wye, as well as in the adjacent and much larger basin of South Wales, they are everywhere conformably overlain by the shale and limestone which, in these tracts at least, compose the base of the Carboniferous rocks. Occasionally, as under the Carboniferous escarpment of the Clee Hills, Salop, these upper beds are of yellow colours. In short, the above generalized section gives an idea of the prevalent distribution of the strata within, and wrapping round, the original Siluria.

Now, whilst in all that region the only organic remains which have been found in this great red and green series, with the single exception of the Crustacean figured on the next page, are fragments of fossil Fishes and a few Plants, we shall presently see that, with mineral conditions to a great extent similar, the widely spread Old Red Sandstone of Scotland, which is of equivalent age, has also yielded abundance of Ichthyolites. This prevalence of Fishes is in striking contrast to all that has been said of the great mass of the contiguous and underlying Silurian rocks, in which no trace of a vertebrated creature has been found, except in the highest member of the system, which ushers in the natural group under consideration.

In Herefordshire and Brecknockshire, as well as in Shropshire, Ichthyolites were formerly described as occurring chiefly in strata where calcareous matter is most diffused,—teeth, bones, and scales of Fishes having been often detected in the cornstones, though the best specimens have been procured in the finely laminated flagstones and marls which are in the vicinity of those concretions. The Fishes of this region, which were first made known to geologists by the publication of the 'Silurian System,' belong to the genera named (by Agassiz) Cephalaspis, Onchus, and Ptychacanthus; and figures of them, from that work, are here repeated in Plates XXXVI. & XXXVII. To these the Pteraspides formerly supposed to belong to Cephalaspis (Pteraspis Lloydii and Pt. rostratus, figured in the

'Silurian System') have since been added. Many others will be noticed in describing the Scottish series.

The lowest Old Red strata in which I had personally observed the remains of the peculiar Fish Cephalaspis when the first edition of this work appeared are at the western slope of the Silurian ridge of May Hill *. In examining the cuttings of the Ross railroad, near Flaxley, my lamented friend Mr. H. E. Strickland † and myself detected a fragment of that Ichthyolite in the very bottom beds of the Old Red, which, containing also certain land Plants, there lie in apparent conformity upon the uppermost Ludlow rocks.

More recently, indeed, the sections near Ludlow, particularly on the right bank of the Teme, have afforded those fresh evidences of a transition from the Upper Ludlow into the Lower Old Red which have previously been adverted to (p. 139), and which render it difficult to draw any arbitrary line (within a few yards at least) as an horizon to separate the two formations ‡. In Shropshire we find, in ascending from the Tilestones into the marls and sandstones with concretions of argillaceous limestone (and the same phenomenon reoccurs near Kington in Herefordshire), that other species of Pteraspis occur, as well as other species of Cephalaspis, and particularly C. Lyellii; and thus we are conducted at once into the great formation which, in parts of Scotland, also contains the same species.

FOSSILS (69). CRUSTACEAN FROM THE OLD RED OF HEREFORDSHIRE.

Stylonurus Symondsii (Eurypterus, Salter, Quart. Journ. Geol. Soc. vol. xv. pl. 10. fig. 1); from Rowlestone, south of the Hay, Brecknockshire.

The cephalic shield of a Crustacean allied to Pterygotus. For figures of this and other species of Stylonurus, see Mr. H. Woodward's paper in the Quart. Journ. Geol. Soc. vol. xxi. p. 482.

In the red ground two miles north of Bewdley, near Trimpley, in Worcestershire, greyish sandy grits and cornstones rise out in undulations. There the cornstones are charged with Cephalaspis Lyellii and Pteraspis Lloydii, and the underlying grits with P. Banksii, Pterygotus Ludensis and eggs of this Crustacean (Parka decipiens), &c., with many remains of Plants, including the small Lycopodiaceous sporangia (Pachytheca).

An important addition was not long since made to the fauna of the Old Red Sandstone of England by the discovery of a Eurypterus at Rowlestone in Brecknockshire, in the lowest portion of those sandstones of the Black Mountain, near Hay, which overlie the cornstones, *d*, of the previous gene-

* See Sil. Syst. pl. 36. f. 13.

† The passage of this portion of the first edition of this work through the press having been delayed until I returned from a tour in Germany, I learned with profound grief, upon my arrival, of the lamentable catastrophe by which, in examining another railroad-cutting, my eminent friend, Mr. H. E. Strickland, had been taken away from those sciences of which he was so great an ornament. The correction of those pages by his hand, during my absence, was one of the last memorials of a friendship which I truly cherished.

‡ Another very interesting section of these Passage-beds, at Linley in Shropshire, has been described by Messrs. G. E. Roberts and J. Randall (Quart. Journ. Geol. Soc. vol. xix. p. 229).

ral section. This unique fossil (Foss. 69) was first brought into notice by my accomplished friend the Rev. W. S. Symonds *, the specimen having been found by the Rev. W. Wenman. In the higher portion of this series, near Crickhowell, I formerly found the scale of a large Fish (Sil. Syst. p. 172), since ascertained to belong to Holoptychius.

Lastly, a new species of the remarkable genus Pterichthys, Ag., so characteristic of the Old Red of Scotland, has been discovered at Farlow, in Shropshire, in a yellow-coloured sandstone, which there occupies the highest portion of the formation, rising out from beneath the shale of the Carboniferous Limestone of the Titterstone Clee Hill, and graduating down into the mass of the red sandstone and subjacent cornstones. This species has been described by Sir Philip Egerton †; and in the meantime it is well to remark that, whilst one form of the genus, which was first detected by Hugh Miller, lies in one of the lower beds of Cromarty, another species occurs plentifully at Dura Den in Fifeshire, where it is also in a yellow sandstone which has always been classed as the upper member of the group.

When we follow this series of red beds from Shropshire and Herefordshire through Brecknockshire and Carmarthenshire into Pembrokeshire, considerable lithological changes are seen to occur. Though the prevailing colour in the last-mentioned county is still red (the 'red rab' of Pembroke), some portions of the rocks consist of dull-green and brown flags or sandstones, and others of hard grey grits, which even resemble certain inferior Silurian deposits; whilst true cornstone or limestone is rare, as are the traces of fossil Fishes. Yet the strata in question, to whatever extent attenuated in some tracts or placed unconformably on the Silurian rocks in others, occupy the same geological position as in the tracts of England and Wales previously mentioned, and lie clearly between the Silurian and Carboniferous rocks ‡. In fact, few better sections of the Old Red Sandstone of Britain, in relation to the rocks beneath and above it, can be offered than are exposed around the magnificent landlocked bay of Milford Haven. (See Map.)

We shall presently show the order of succession in rocks of the same age under a different and more slaty aspect on the south side of the Bristol Channel, in Devonshire, and indicate that, with a considerable change in their composition and a great increase in calcareous matter, the strata there contain many Mollusks and other marine animals unknown in the Silurian region, and equally distinct from Carboniferous species.

Let us, however, previously consider the nature of the Old Red Sandstone of Scotland, where, preserving much of the same mineral character

* See Edin. New Phil. Journ., new ser., vol. vi. Oct. 1857.

† In a sequel to a paper by Professor Morris and the late Mr. G. E. Roberts on the Carboniferous Limestone and Yellow Sandstone of Oreton and Farlow: Quart. Journ. Geol. Soc. vol. xviii. p. 103.

‡ The yellowish sandstones which, in Pembrokeshire, form the summit of this group may, at least in part, be classed as the base of the Carboniferous rocks; that is, they are beds of transition in which Lower Carboniferous fossils have been detected.

as in the parts of England just mentioned, the group is more grandly displayed in the North-eastern Highlands than in any other part of Europe.

Old Red Sandstone of Scotland.—Dwindling away from its copious development in Brecon, Hereford, and Salop, the Old Red Sandstone of the North of England is, as before stated, little more than a single band of coarse conglomerate, a small skirting mass, lying between the Silurian and Carboniferous deposits of the Lake-district of Cumberland. This single member, of a series so copious elsewhere, there reposes on the truncated edges of the older slaty rocks.

In Scotland, however, the deposits of this age are more expanded than in any part of England and Ireland. Ever since the admirable writings of Hugh Miller, and his description of its fossil Fishes, the Old Red Sandstone has been a name so popular that in North Britain, at least, my countrymen, although they admit the truthfulness of the identification of the group with the 'Devonian' of other countries, have naturally clung to the long cherished term.

In the following sketch of the development of the Scottish Old Red Sandstone, I commence with a brief account of it in the countries lying between the English border and the great valley of the Forth and Clyde. Now, although I have myself examined strata of this age at various points within this region during bygone years, I am too happy to avail myself of the fresh light which has been thrown upon that southern region since the last edition of this work by my colleague Mr. Geikie, who has furnished me with the following valuable notice:—

"In the southern half of Scotland, between the Grampians and the Cheviots, the Old Red Sandstone is abundantly developed. Recent observations lead me to regard it as divisible there into three groups, as under:—

"*a.* Upper red and yellow Sandstones and Conglomerates, with Holoptychius, Pamphractus, Glyptopomus, Cyclopteris Hibernica, &c. *b.* Middle series of green, grey, and reddish Sandstones, Flagstones, and Conglomerates, with a copious intermingling of contemporaneous volcanic rocks: Pterichthys major in the upper part. *c.* Lower red, chocolate, and grey Sandstones, Flagstones, and Conglomerates, sometimes with enormous intercalated masses of trappean rocks: Cephalaspis Lyellii and Pterygotus Anglicus.

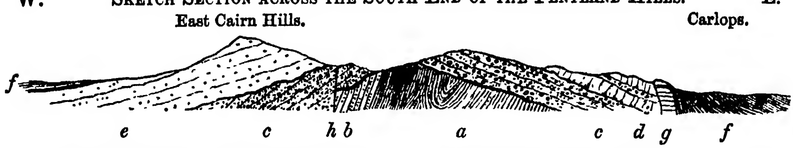
"*c.* The lower group in the Lesmahago district is found passing down conformably into the Upper Silurian shales, as already described by Sir R. Murchison (*ante*, p. 160); and the same passage appears to be traceable in the Pentland Hills (*b*, in the following diagram). This group attains a great development between the basin of the Clyde at Lanark and the Ayrshire Coal-fields*, reaching a thickness of perhaps 7000 feet. It is well seen at the Falls of Clyde, where it consists of dark chocolate-coloured sandstones. Round Tinto it contains masses of trappean conglomerate, which, along with

* See Quart. Journ. Geol. Soc. vol. xvi. p. 312.

interbedded felspathic rocks, extend south-westwards towards the source of the Nith. In the valley of the Irvine, at Lanfine, it consists of a grey micaceous flagstone, with trappean conglomerates and felspathic traps, and it has there yielded some fine specimens of Cephalaspis Lyellii. The Ochil Hills belong to this same lower division. They contain a thick series of coarse trappean conglomerates and ashy beds, with enormous sheets of porphyritic and amygdaloidal felspathic trap. They pass under a set of red sandstones containing Parka decipiens *. It is these trappean rocks which in a great anticlinal arch are prolonged into the chain of the Sidlaw Hills of Forfarshire. In the east of Berwickshire, near Reston, a group of very ashy sandstones and conglomerates is overlain unconformably by the Upper Old Red Sandstone of the Merse. They have yielded fragments of plants and Pterygotus, and are probably referable to the Lower Old Red Sandstone †.

"*b*. The middle group is one which I have only recently detected, and of which I do not yet know fully the relations. Perhaps it may eventually prove to belong in part to the Lower Old Red series. In the Pentland Hills it consists of dull greenish sandstones, greywackès, and conglomerates, with ashy beds and very thick sheets of various felspathic rocks, the whole series reaching a thickness of many thousand feet. As shown in the accompanying section, it rests (*c*, *d*) unconformably upon highly inclined Upper Silurian

W. SKETCH SECTION ACROSS THE SOUTH END OF THE PENTLAND HILLS. E.



a. Upper Silurian shales, sandstones, &c. *b*. Red sandstones and conglomerates, possibly marking the base of the Lower Old Red Sandstone. *c*. Thick conglomerates and grits forming here a Middle division of the Old Red Sandstone. *d*. Felspathic lava-beds interstratified with *c*. *e*. Upper Old Red Sandstone. *f*. Carboniferous sandstones, shales, &c. *g*. Intrusive greenstone coming up along a line of fault. *h*. Fault. (See also page 159.)

shales (*a*), and on the red beds which may there represent the base of the Lower Old Red Sandstone (*b*). Traced south-westward, this series seemed to me likewise to overlap unconformably the Lower Old Red conglomerates and sandstones of the Tinto district. It is covered unconformably by the Upper Old Red Sandstones, the junctions being well seen to the south-west of the Pentland range. It thus appears to be a series intermediate between the upper and the lower zone of the Old Red Sandstone, from each of which it is separated by an unconformity. No fossils have yet been found in it in this region; so that it cannot be linked by organic remains with the middle series of the North of Scotland, to which, of course,

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it presents no lithological resemblance. More recent observations in Ayrshire, however, lead me to suspect that this middle series is not merely an unconformable upper part of the Lower Old Red Sandstone, but forms a distinct member of the formation. Between the town of Ayr and the Vale of Girvan, and stretching eastwards towards Nithsdale, there occurs a thick mass of reddish and chocolate-coloured sandstone, with large intercalated sheets of felspathic trap and ashy beds. This series is comparable with that of the Pentland Hills. It rests unconformably on the Silurian rocks already described, and on certain red sandstones and conglomerates which may represent the Lower Old Red series; and as it continues to dip steadily northward for ten or fifteen miles, its thickness must be great. It is covered unconformably by Lower Carboniferous rocks, there being no Upper Old Red Sandstone in the district. Near the Heads of Ayr, in a hard reddish-grey micaceous sandstone, lying in the upper part of the series, abundant plates of Pterichthys major have been found. (See sections on pp. 156 & 157.)

"*a.* The Upper Old Red Sandstone (*e* of the section) occurs extensively in the eastern division of the southern half of Scotland. It has long been known at Dura Den in Fife, where its yellow sandstones have yielded Holoptychius, Pamphractus, and other Fishes. An outlier of it lies unconformably on the Lower Old Red Sandstone at Clashbinnie, in the lower part of the basin of the Tay; and another occurs in a similar position near Arbroath. In Haddingtonshire and Berwickshire it consists of a lower thick mass of coarse brecciated conglomerate, lying unconformably on the Lower Silurian greywackè, and of an upper series of red sandstones and marls containing Cyclopteris, Bothriolepis, &c., and passing up into the base of the Carboniferous system.

"It thus appears that, between the Grampians and the Cheviot Hills, what has been called 'Old Red Sandstone' consists of three zones:—a *lower*, graduating down into Upper Silurian shales; a *middle*, bounded both above and below by an unconformable junction; and an *upper*, which shades up into the Carboniferous rocks."

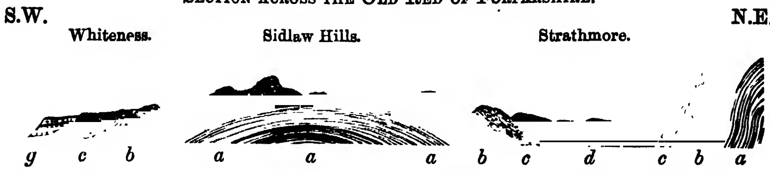
It is highly satisfactory that the triple division of the Old Red Sandstone, which I established by my observations in the North of Scotland, is thus supported by a correct survey of the country south of the Grampians. In the sequel, proofs will be adduced of a like triple classification of this natural group where it assumes the Devonian or more slaty structure.

Indications of the presence of the uppermost member of the Silurian rocks also exist in Forfarshire, and particularly on the flanks of the Sidlaw Hills, where the grey paving-stones of Arbroath repose upon clay-slate, and contain the Crustacean Pterygotus Anglicus, which appears not to be identical with the great Pterygotus of Shropshire* (see pp. 238, 239). The following general section over a part of that region is given by Sir C.

* Quart. Journ. Geol. Soc. vol. vii. p. 169.

Lyell in his 'Manual of Geology.' Since this section was made, great additions have been made to our acquaintance with the details of the Old Red series in this part of Scotland. Some years ago, in company with

SECTION ACROSS THE OLD RED OF FORFARSHIRE.



a. Clay-slate. *b.* Grey paving-stone and tilestone, with green and reddish shale, containing Pterygotus and Parka decipiens*. *c.* Red conglomerate. *d.* Red sandstone, with Ichthyolites &c. *g.* Red shale or marl, unconformable to the lower rocks.

Mr. Powrie, I saw that the mass marked *b* is, on the eastern or mountainous side (where it reposes on the crystalline rocks), a very hard and grey gritty conglomerate charged with Parka decipiens†.

Mr. Powrie has since shown that, after great flexures, the lower strata, passing under red sandstones and conglomerates, reappear on the east coast, their prominent fossiliferous member being the Arbroath flagstones. He has, indeed, communicated two interesting memoirs to the Geological Society on this subject‡. In the first of these he shows that, east of the Grampians, all the old stratified sediments of Forfar which he has examined consist of these two divisions only of the Old Red Sandstone. In the second he indicates how their equivalents in Fifeshire are surmounted by an Upper Old Red deposit—the yellow sandstone of Dura Den, so celebrated for its numerous and peculiar Ichthyolites.

It was indeed very gratifying to find that, since the last edition of 'Siluria' appeared, both Mr. Powrie and his very skilful coadjutor Mr. Page, whose writings on geology are so widely known, had seen fit to acknowledge that the lower sandstones and flags of Forfar, with their Cephalaspis, Pteraspis, Pterygotus, and Parka decipiens, are, as I had previously placed them, inferior to, or older than, the great fish-beds of the north, viz. the Caithness Flags. These authors admit, in short, that the Lower Old Red of Ross, Sutherland, and Caithness, which I described forty years ago, and of which I treat in the sequel as the base of that series, is the true equivalent of the Arbroath paving-stones and the lowest Old Red of Forfarshire §.

* My valued friend the late Rev. John Fleming, D.D., who wrote original papers on the organic remains of the Old Red Sandstone, first assured me that a fruit-like body found in Fifeshire and in the Arbroath paving-stones of Forfarshire was unquestionably a vegetable, and could not be classed as the egg of a Mollusk as suggested by Lyell, or as the egg of a Batrachian as more recently proposed by Mantell. The figure which Dr. Fleming gave in the year 1831, Edin. Journal of Nat. Science, vol. iii. pl. 2. f. 5, certainly favoured the opinion that it was an aggregate fruit. Since then he examined both the upper and under surfaces, and quite satisfied himself that it is a receptacle, and that the round covering bodies are carpels or fruits. It is now known as the Parka decipiens, and is usually regarded as the eggs of Crustaceans. See p. 239, and notes, pp. 238, 239.

† See also Page's 'Advanced Text-book of Geology.'

‡ Quart. Journ. Geol. Soc. vol. xvii. p. 534, and vol. xviii. p. 427.

§ Whilst these pages were going through the press, I received from the Natural History Society of Montrose photolithographic representations of a splendid specimen of Pterygotus Anglicus, found in the Lower Old Red Sandstone of Carmylie, Forfarshire. Accompanying the Report of the

Among the stratigraphical comparisons which have been made, Professor Harkness has shown that between the Bridge of Allan and Callender there is an elevated trough-shaped mass of the Old Red Sandstone, in the lower portion of which conglomerates, followed by beds containing Cephalaspis and Pterichthys, are surmounted by red shale, grey sandstone, &c.* Thus we see that in all the southern and central tracts of Scotland the lower beds are characterized by the same fossils; and it will presently be shown that these beds have a true equivalent in the northernmost counties, but are there surmounted by a rich ichthyolitic group, the Caithness Flags, which is ill represented in the central or southern counties.

Again, the classical work of Agassiz on the Fossil Fishes of the Old Red Sandstone has of late years received valuable additions through the labours of Sir P. Egerton, who has rectified the nomenclature by suppressing double names applied to the same Fish, and has brought out in relief the true typical forms as described by Agassiz, Hugh Miller, M'Coy, himself, and others†.

Northern Region of the Scottish Old Red Sandstone.—It has already been shown that in one part of the South of Scotland the uppermost Silurian rock, with its fossils, is overlain conformably by red shale and sandstone (p. 161)‡. Such an Upper Silurian basis is, however, wanting in the Northern Highlands; and the reason is obvious. We now know that rocks of Lower Silurian age, associated with, and reposing on, old Cambrian conglomerates, have there been metamorphosed into a crystalline state, and that a great change of the crust took place in the former outline of land and sea, in consequence of which, as we have every reason to think, no Upper Silurian sediment was ever accumulated.

To determine, however, with precision the extent to which those crystalline Highland rocks, whether quartzose, gneissose, micaceous, or chloritic, with subordinate limestones, may represent various Silurian subformations must still be a work of long labour. In the meantime it is clear that, ranging south-west from Sutherlandshire into Ross-shire, they constitute in Loch Alsh and Kintail that lofty and steep watershed so near to the west coast of the Highlands, the strata of which, dipping rapidly to the E.S.E., are, after numerous undulations, transgressively surmounted by the lower member of the Old Red Sandstone of the eastern counties (see the section at p. 169).

Wherever these two great systems of metamorphosed Lower Silurian rocks and the overlying Old Red Sandstone are in contact, the direction of the one is completely discordant with that of the other. Thus, whether

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Director of the Montrose Society are extracts from a description of the Basin of Montrose, by the Rev. Hugh Mitchell, with figures of the peculiar Fishes of a band of the Old Red Sandstone of Forfarshire, viz. Parexus incurvus, Agass., Euthacanthus MacNicoli, Powrie, Climatius uncinatus, Egerton (Quart. Journ. Geol. Soc. vol. xx. p. 422 &c.). This band is above the Arbroath or bottom-beds, and probably represents a portion of the Caithness Flags.

* Quart. Journ. Geol. Soc. vol. xviii. p. 253.

† See Quart. Journ. Geol. Soc. vol. xvi. p. 119 &c.

‡ See also Quart. Journ. Geol. Soc. vol. vii. p. 168; vol. viii. p. 386.

the older system be viewed in the western part of Sutherland and Ross, where limestones are intercalated in quartzites, or in the eastern tracts of those counties, where gneissose and micaceous schists prevail, the strike which is most frequent is seen to be from *N.N.E.* to *S.S.W.*, the dominant dip being to the E.S.E. The Old Red conglomerate of the east coast is, on the contrary, thrown off the promontories of the older system in devious directions, the prevailing dip in Caithness being to the N. of E. (and even N.N.E.), in the northern part of Ross-shire to the S.S.E., and on the south side of the Murray Frith again to the N.N.E. A complete unconformity, in short, is everywhere observable, independent of the fact that the younger deposit is literally made up of the débris of whatever portion of the older it happens to rest upon. In this way we observe that in one spot the conglomerate is chiefly made up of quartz-rock; in another, of mica-schist; in a third, of gneiss; in a fourth, of granite; and occasionally of all these and other varieties of the older system mixed together.

Then, again, nothing can be more dissimilar than the physical outlines of these two rock-systems. Whilst the quartzo-micaceous, crystalline rocks resemble in outward form a tumultuous sea, the observer who stands on the conglomerate which lies on their eastern edges sees beneath him, to the east, the highly contrasting outline of soft undulations which, in the low countries of Caithness, Easter Ross, Inverness, Nairn, and Elgin, dip gradually away to the seaboard. So strong is this contrast, that the geographer unacquainted with geological science would at once say that these two rock-systems belonged to very different epochs in the history of the earth's crust.

In no tract of Britain, indeed, is there so clear a succession of the whole group of the Old Red Sandstone, properly so called, as that which is exposed on the north-eastern shores of Scotland. This order is especially well seen when the observer, having made himself well acquainted with the copious lower conglomerates and sandstones which fringe the crystalline rocks of Elgin, Nairn, Inverness, and Ross-shire, passes through Sutherland into Caithness and the Orkney Islands. This last is the region selected thirty years ago by Professor Sedgwick and myself* as affording what we then conceived to be the clearest example of the extended features of that great group of the British series with which we long afterwards compared, as an equivalent in time, the slaty rocks, schists, sandstones, and limestones of Devonshire. (See pp. 271 &c.) Having twice revisited the north-east coast of Scotland since the first edition of this work was published, and having been confirmed in my former views concerning the general physical succession of the masses, a brief sketch of the leading phenomena is now given. This *résumé* is the more called for, as geologists who have never examined this north-eastern region, and have been

* Trans. Geol. Soc. Lond., 2nd ser., vol. iii. p. 125, with map of the Highlands, sections, and some figures of the Caithness Fishes.

disposed to consider the Old Red Sandstone a kind of local formation only, have been unwilling to regard it as the full equivalent in time of the Devonian rocks of other countries.

The massive conglomerates and intercalated red sandstones of the north-east coast, which occupy a great thickness of strata in Easter Ross, Cromarty, the Black Isle, and adjacent parts of Inverness-shire, and which, flanking the Oolitic tracts of Dunrobin and Brora, range northwards from Sutherland into Caithness, are very distinct in mineral character and relations from the ancient Cambrian conglomerates and grits of the west coast. Whilst the latter underlie all those quartzites and limestones which are now known to be of Lower Silurian age, the great pebble- and boulder-beds of the east coast and its inland recesses never assume the subcrystalline character of some of the western masses. On the contrary, they overlap all such rocks; and, often containing gigantic boulders, invariably derived from some adjacent crystalline rock, they graduate into, and alternate with, masses of grit and sandstones as sectile and as well fitted for building-purposes as many freestones in the British Isles. Indeed, at places, the red sandstone associated with the conglomerate assumes so variegated a character, with green spots and stripes, or earthy concretions, that, in early days, German geologists, unacquainted with the exact relations of the deposit, and judging from mineral characters only, would have referred such rocks to the 'Bunter Sandstein.'

The reader who desires to become better acquainted with the different varieties of such conglomerates and sandstones may peruse the descriptions given of them by Jameson, Boué, and the earlier writers, as well as by M'Culloch, Sedgwick, and myself.

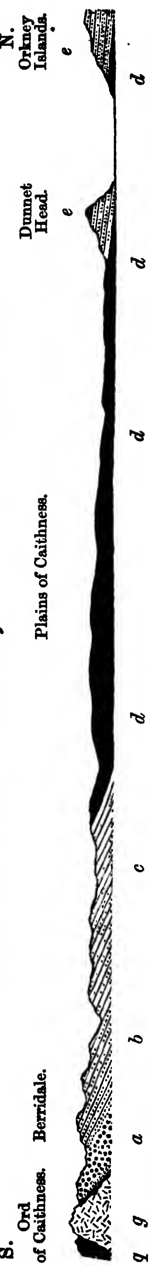
Among the various authors who have described them, the lamented Hugh Miller stands preeminent. Born upon the Old Red Sandstone of Cromarty*, he has shed a bright lustre over this deposit of his native tract, and has expounded with a surprising sagacity the wonderful organization of many of its fossil Fishes, and thrown the clear light of zoology upon these old pages of geological history.

The term Old Red Sandstone having thus been rendered classical, the name may well be retained as a synonym for the great group, of intermediate age between the Silurian rocks beneath and the Carboniferous formation above it, which, in those countries where it assumes more calcareous, schistose, and slaty characters, is termed 'Devonian.'

Among the older crystalline rocks which, rolling over from the west, constitute the masses out of which the red sandstone and conglomerate

* See Hugh Miller's remarkable work, 'The Old Red Sandstone,' in the dedication of which to myself he alludes to our both being born upon the Old Red Sandstone. In physical geography, Cromarty, the birthplace of Miller, forms a part of the peninsula of Ross-shire known as the Mull-Buy, or the Black Isle, in which my paternal estate of Taradale is situated, and where, as in the adjoining property of Red Castle, varieties of the building-stone have long been quarried. Ross-shire now affords, indeed, so many quarries of building-stone, both light and dark red, and sometimes ribboned or spotted, that in proceeding from Inverness to Sutherlandshire by Dingwall and Tain the traveller has ample evidence of the varied nature of the rock.

GENERAL SECTION OF THE OLD RED SERIES (CAITHNESS AND ORKNEY ISLANDS).



a. Old Red conglomerate. *b.* Red sandstone. *c.* Thin-bedded sandstone passing into flagstones. *d.* Bituminous schists and hard flagstones, with limestones &c. *e.* Upper Old Red. *g.* Granite. *q.* Quartz-rock and mica-schist.

NOTE.—*a* and *b* are the equivalents of the Arbroath and Dundee beds.

of the east coast have been formed, mica-schists prevail in Easter Ross; whilst as we proceed northwards into Sutherland, particularly in the Scarabin Hills, quartz-rocks predominate. Now the quartzites of these mountains present just the same bedding, and alternate with schists, as in the western parts of the country, where the Lower Silurian fossils have been discovered. Thus, in descending from the Scarabins towards the sea, we meet with a regular succession of crystalline or subcrystalline, light-coloured, thin-bedded quartzites with argillaceous wayboards, and presenting all the aspect of a sedimentary origin, which, rising at high angles to the summits, are followed on their eastern flanks by other siliceous courses (some micaceous), of various colours from dull purple-brown to grey. At certain spots these quartzose rocks are broken up and penetrated by granite. It is upon the edges of these rocks, as ranging from the Ord of Caithness by the Scarabins to the Morvein Hill, that the base of the Old Red series of Caithness rests, the conglomerates composing the last-mentioned of these mountains occasionally rising, along this fringe only (as Hugh Miller has well remarked), to higher altitudes than the older crystalline rocks.

Let us now consider the overlying series in a true ascending order, by proceeding from the inferior red sandstones and conglomerates, through the central masses of dark-grey flagstones and schists, to the higher sandstones which stand out in the northern headlands of Caithness and the Orkney Islands. The accompanying diagram indicates this succession in a general and compendious manner, the many detailed flexures and breaks in the strata being omitted.

In describing the different parts of the lowest member of the Old Red Sandstone, it would be superfluous to enumerate all the examples of splendid and massive conglomerates and sandstones, particularly those of Easter Ross, which, reposing on the

crystalline rocks of Ben Wyvis and other mountains, constitute the base of this series. Exhibitions of such rocks may be seen in the Hills of Moy near Brahan Castle, and again in ascending the Orron, Connan, and Alness Rivers; and they range thence eastwards all along the southern flanks of Ben Wyvis and its associated mountains, and, traversing the Kyles of Dornoch, extend through the eastern parts of Sutherland into Caithness.

On this coast, beginning at the north side of the mouth of the Beauley Loch, there is a most splendid exhibition of the coarsest of these conglomerates, chiefly made up of granite and gneiss, on the shore between Kessock Ferry and the House of Drynie, and along the mouth of Munlochy, particularly at the point called Craigie How. Thenceforward to the north they appear at intervals, and are exhibited at Ben-a-Bhraggie, close to Dunrobin, and in the ridge extending to Golspie and the Ord of Caithness, and there forming the base on which the Oolitic deposits of Brora are deposited, as described by me in 1826 *.

In Ross-shire the banks of the River Alness, particularly near Ardross Castle, the seat of Mr. A. Matheson, M.P., exhibit intercalated masses of the red oxide of iron, amid conglomerates and sandstones. Other splendid examples of such conglomerates are seen in the deep narrow gorge in which the Alt Grant flows. It is in these beds, particularly near Mount Gerald, that the bituminous mineral called Albertite has been found, apparently in lines of joint, and also at several places along the south-eastern flank of Ben Nevis, and in the associated schists of Strathpeffer. This Albertite has possibly been derived from the conversion of the Fishes and associated marine Plants of the deposit into bitumen, which, exuding from the beds, has flowed into the chinks and vertical fissures of the rock, and has there been indurated. The tenuity of these linings of the joints renders it highly improbable that this mineral will ever be found in sufficient quantity to render it of commercial value, like the Albertite of New Brunswick.

Though in many of these localities, particularly in Ross-shire, these conglomerates are of vastly greater dimensions than in their extension into Caithness, there is no tract in which their relation to the overlying richly fossiliferous deposits is so well seen; and hence the section selected as a type is that which proceeds from the maritime promontory called the Ord of Caithness, where granite has been powerfully intruded among the older rocks. There, and in the recesses extending south-westward from Braemore along the edges of the quartz-rocks of the Scarabin Hills, are exposed fine masses of conglomerate and sandstone dipping north-eastwards at a low angle. The same conglomerates form, in fact, the inland girdle of Caithness, rising up on the west from beneath the great flagstones of that low undulating country, and separating those strata, so replete with fossil Fishes, from the above-mentioned crystalline rocks.

* Trans. Geol. Soc., 2nd series, vol. ii. p. 293.

Let the geologist proceed northwards from the edge of the crystalline rocks, and he will clearly see, first, that the lowest strata of conglomerate and red sandstone, as made up of the crystalline rocks, alternate with, and pass into, deep-coloured, thin-bedded, micaceous red sandstones, as in the Cliffs of Trefad and the Old Man of the Ord, which constitute the natural and conformable base of the flagstone series of Caithness.

In order to convey to the reader some notion of the natural features of the lower portion only of this fine succession, a small sketch is annexed, as taken from the footpath on the northern side of the Ord, at a spot called Badna Bae.

VIEW OF THE OLD RED SUCCESSION, FROM NEAR THE ORD OF CAITHNESS.

The foreground is made up of the rude conglomerate, *a* of the section at p. 255, here chiefly composed of huge blocks of granite (the nearest rock, and of which the hut is built), though other smaller materials are of quartz-rock and mica-schist. This bottom rock of the series is followed by deep-red sandstones, which occupy the next headland, known as the Man of the Ord, *b* of the diagram; whilst all these strata, inclining to the north, pass beneath the flagstones of Caithness, which occupy the distant low headlands (*c*, *d*, of the long section, p. 255). (See description by Sedgwick and myself, Trans. Geol. Soc. 2 ser. vol. iii. p. 139.)

It would be a difficult task to endeavour to assign an average thickness to the accumulations of sandstone and conglomerate (the sandy beds being sometimes the lowest) that constitute the lowest member of this group, since it is in the very nature of pebbly accumulations which were formed either on coasts or in bays washed by the waves of a former sea to present the most variable dimensions. Independently of the conglomerates, and the associated sandstones, often very finely laminated, these deposits must have occupied a long lapse of time in their accumulation. Since the last edition of this work, an important confirmation of my view respecting these lower sandstones being the equivalents of the Arbroath beds, or the lowest Old Red

of Scotland, has been made by Mr. Charles Peach. That successful fossilist detected in strata near Lybster, much older than the Caithness flags, the remains of a portion of a Pteraspis,—an Ichthyolite never yet found above the lowest of the three divisions of the Old Red Sandstone.

The red sandstone of this lowest zone, assuming gradually a flag-like character, and becoming of a purplish tint, passes up by other beds, *c*, into those grey-coloured flagstones which, forming a large portion of the county of Caithness, are so well known to geologists through the description of their imbedded fossil remains by Agassiz and Hugh Miller. From the environs of Lybster, where the strata (*d* of the diagram at p. 255) begin to contain fossil Fishes, these flagstones present a general uniformity in their lithological characters; and, though here and there so calcareous as to have been in parts formerly burnt for lime, they are, on the whole, to be regarded as a great series of hard, argillo-siliceous beds of great tenacity, in which, within the last forty years, large and valuable quarries have been opened out.

The most satisfactory study of these flagstones, from their lower members near Dunbeath to their central parts at Wick, and thence to their highest strata on the shores of the Pentland Frith, where they pass up into, and are covered by, the upper red sandstones of Dunnet Head, is to be made in the precipitous coast cliffs, which, abraded by the surges of the ocean, exhibit many remarkable small bays and headlands, on the sides of which the hard flagstones present their rough and jagged edges*. The thickest beds, near Wick, are from 14 to 15 inches thick, and, when quarried for building-purposes, occasionally furnish blocks of 20 feet in length, which are of great tenacity and durability. In some of the calcareous courses Mr. C. Peach has discovered that the fragments of fossil Fishes have in certain spots been ground down to a powder, which constitutes a large portion of the matrix of the rock.

Many of the beds are so bituminous, owing to the quantity of animal matter they contain, that even when described by me in 1826 they were termed the 'bituminous schists' of Caithness, bitumen being seen to exude naturally from them†. Having obtained specimens from near Barrogill Castle, collected by Mr. Peach, I submitted them to analysis by Dr. Hofmann, who, according to the report given in the Appendix C, attaches considerable value to this mineral if it be obtainable in sufficient masses. Now, as it has been found profitable to distil 'stone-oil,' or petroleum‡, from beds of Secondary age charged with fossil Fishes, in high recesses of the Alps, we may certainly infer that these Palæozoic strata lying so near the sea may yield so much bitumen that, in consequence of it and the

* Not having personally examined all the coast between Wick and Latheron Wheel, I requested Mr. C. Peach to do so; and he detected the existence of an axis at Sarclet, by which conglomerates are again brought up, and are thrown off to the South and to the North, thus passing on either side under the fish-bearing flagstones. These features are not represented in the general section, p. 255.

† See Trans. Geol. Soc. Lond., 2nd ser., vol. ii. p. 314.

‡ See my paper on the Bituminous Schists of Seefeld, Proc. Geol. Soc. Lond. vol. i. p. 39.

largely increasing demand for its valuable flagstones, the hard and sterile parts of Caithness may become a well-peopled and industrial tract.

Besides fossil Fishes, the Caithness flagstones contain innumerable shells of Estheria (a small bivalved Crustacean) and numerous fossil Plants; and these organic remains will presently be considered *.

Continuing to trace the ascending order of the Old Red Sandstone series of Caithness into the Orkney Islands, it is to be noted that the flagstones, usually of a dark-grey colour, but here and there of a purplish tint, graduate upwards into those higher light-red and yellow sandstones and grits which, constituting the northernmost point of the mainland, Dunnet Head, are again seen at Hoy Head and in many parts of the Orkney and Shetland Islands, where they occupy a similar relative position. Some of these upper sandstones (*e*, p. 255), into which there is a perfect transition from the harder flagstones, might in hand-specimens often be mistaken for the beds which underlie the Caithness flags, both in colour and composition. Others are light-coloured, yellowish, fine-grained freestones, notably in the Isles of Pomona, Shapinsha, and Eda. In these upper sandstones Land Plants prevail, particularly in the Shetland Isles; and according to Dr. Hooker they are referable to Calamites, generically resembling, but of species differing from, the forms known in the Carboniferous rocks †.

Seeing that there is no sign in this northern region of a further passage upwards into any strata which can be classed as Carboniferous, the triple subdivision of the Old Red Sandstone which I have long recognized is adhered to. The equivalents of this great series will afterwards be noted in other parts of the world, and especially in Russia, where strata occupying the same place in the general series of deposits are found to contain the Mollusca of Devonshire commingled with the Ichthyolites of Scotland.

The same succession, from lower conglomerate and sandstone to overlying Fish-beds, which occurs at Dunnet Head and the Orkney Islands is exhibited between the interior crystalline rocks and the coast in the counties of Inverness, Nairn, Elgin, and Banff; but in this range the Upper Old Red is wanting ‡.

The extent to which the variation of the lithological characters of the deposits in their range southwards has affected the distribution of the organic remains is explained in the sequel.

Animal Remains of the Old Red Sandstone.—When Agassiz completed his remarkable analysis and history of the fossil Fishes of this deposit, the number of species enumerated from Britain alone amounted to sixty-five; and this number has since been augmented. Referring the student to

* The most extensive quarries are situated a few miles east of Thurso, having been opened out upon a very large scale by Mr. G. Traill, M.P., of Castle Hill. The flagstones are occasionally of gigantic dimensions, and often present casts of Plants upon their surface.

† See Quart. Journ. Geol. Soc. Lond. vol. ix. p. 49, and further on, p. 271.

‡ The late Lady Gordon Cumming, of Altyre, was the discoverer of many of these fossil Fishes; and the exquisite manner in which that accomplished lady and her eldest daughter sketched and co'oured them is duly recorded in the pages of Agassiz's classic work. (See Poissons du Vieux Grès Rouge, *passim*.)

that monograph, as well as to the fervid writings of Hugh Miller and to the memoirs by Egerton and Huxley, let us now, mentioning some of the principal types, endeavour to determine the order in which these Ichthyolites appear geologically, or in the successive layers of this group of rocks.

It has been shown (p. 133 *et seq.*) that along the frontier of the Silurian rocks in Shropshire and Herefordshire, where a true mineral transition is seen to take place between the Upper Ludlow rock and the base of the Old Red Sandstone, there is also a gradual passage from the fossil Fishes of the one to those of the other. Thus, even beneath the lowest of the Bone-beds of the Upper Ludlow rock we have Pteraspis, and, again, in the chief Bone-bed Plectrodus mirabilis and Onchus Murchisoni, associated with Pterygoti and many Shells known in the beds below. In ascending to a higher stratum most of those mollusks disappear; and, although the same Onchus is still found, we first meet with two species of the genus Cephalaspis added to Pteraspis in those strata which begin to assume the lithological characters of the Old Red Sandstone. In a word, the Tilestones, or beds of passage, considered in a broad sense, possess at their base a Shell or two and a Fish-defence, with Crustacea of the Upper Ludlow rock, and in their upper parts, which begin to graduate into cornstones, we first find the characteristic Fishes of the Old Red Sandstone. It follows, therefore, that as the grey, flag-like strata which pass up into reddish beds may either be viewed as the termination of the Silurian or the commencement of the Old Red, the *genera* Cephalaspis and Pteraspis are typical both of the uppermost Silurian and the lowest zone of the Old Red or Devonian group; in truth, as we now know that the variegated concretions called cornstones are traceable down to within a very few feet of those transition-beds, and as Cephalaspis Lyellii, Pl. XXXVI. f. 1–8, and two species of Pteraspis, ib. f. 9 & 10, abound in them, there can no longer be any doubt on this point. For a popular acquaintance with the oldest recognized Ichthyolites of the Old Red Sandstone, the reader is referred to the figures in Plates XXXVI. & XXXVII.

In adopting this view, we remove one of the difficulties which was presented to the mind of Hugh Miller, in his endeavour to determine the order in which the different Ichthyolites of the Old Red Sandstone of Scotland successively made their oppearance. Grouping the Caithness flagstones in the lower division, and unable, on the one hand, to detect a Cephalaspis in them, or on the other to find the Fishes of his north-eastern tracts in the central parts of Scotland, he was naturally induced to suggest that the beds with Cephalaspis * would be found to lie above the fish-beds of Cro-

* In formerly adopting the belief that the cornstones with Cephalaspis generally represented the middle beds of the Old Red Sandstone, Hugh Miller was quite justified; for it was then supposed, even by myself, that these concretions occupied the central part of the group; whilst we now know that their inferior portion actually graduates downwards into the Tilestones and summit of the Ludlow rock. Again, it was formerly believed that a Dipterus (a marked Caithness genus) had been found in the Upper Ludlow rock. This was a mistake in the original 'Silurian System;' for in no subsequent researches has the smallest fragment of a Dipterus been detected in the bone-bed of the Upper Ludlow rock.

marty and Caithness. On looking, however, to the physical order of the masses in that northern region (section, p. 255), we see that this view cannot be retained; for the bituminous schists of Caithness are comparatively high in the series, and, resting upon a great thickness of sandstone and conglomerate (*a*, *b*, *c*), are overlain by the upper zone of the group only. According to my view, therefore, as founded upon a clear order of infraposition, and also on the occurrence of a Pteraspis, the conglomerates and sandstones which underlie the flagstones of Caithness (*a*, *b*, of section, p. 255) are clearly the equivalents in time of the lower cornstone strata of England. This rectification is of considerable importance, since good geological text-books, until very recently, following Hugh Miller, have placed the Caithness Flags in the lowest division of the Old Red Sandstone*.

We may also, indeed, clearly infer that although the Arbroath paving-stones, with their Pterygoti, do not represent the uppermost Ludlow rocks, still it follows that the Cephalaspis-beds of Forfarshire must fall into the lower division of the Old Red group.

In Shropshire and Herefordshire the true base of the Old Red Sandstone, properly so called, is a red rock containing Cephalaspis and Pteraspis (see pp. 141, 244 *et seq.*) and gradually passing down into the grey Ludlow rock; and in both of these contiguous and united strata, remains of large Pterygoti are found, but of different species in the two bands. Now, although the Arbroath paving-stone and the grey rocks ranging to the north of Dundee much resemble lithologically the uppermost Ludlow rock, they contain the Cephalaspis Lyellii, with another kindred species, and are therefore to be classed with the Devonian rocks, though they must, under all circumstances, be viewed as at or near the base of that natural group †. In speaking of the oldest member of the Old Red Sandstone as characterized by the Cephalaspis Lyellii, I repeat my conviction that, in the North-eastern Highlands and Caithness, this lower zone is represented by the vast thickness of thin-bedded red sandstone and conglomerates with Pteraspis which has already been adverted to as lying beneath the Caithness flags. (See Quart. Journ. Geol. Soc. vol. xiv. p. 503.)

In the autumn of 1859 I examined the eastern flank of the Grampians with Mr. Powrie, having previously surveyed the coast of Forfar; I then satisfied myself, by finding the Parka decipiens in schists subordinate to

* In the last or 6th edition of the Elements of Geology, p. 527, Sir Charles Lyell has admitted the validity of my view.

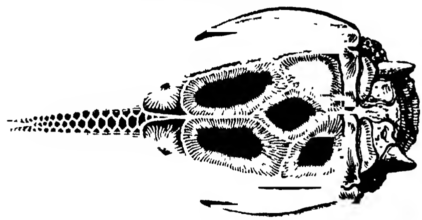
† In a communication made to the British Association at Leeds, in 1859, Mr. D. Page offered some "Further Contributions to the Palæontology of the Tilestones, or Silurio-Devonian strata of Scotland." He confirmed my original view (see pp. 160 *et seq.*) that the Lanarkshire black schists are Upper Silurian, and added many fossils, collected by Mr. Slimon, viz. Pterinea, Orthonota, Nucula, Avicula, Spirorbis, &c., together with new forms of Stylonurus, a Crustacean allied to Eurypterus, all of which sustain the inference I formerly arrived at. The paving-stone of Forfarshire zone, which I consider to be higher in the series, and the true base of the Old Red or Devonian, has been enriched, through the labours of Mr. Page and Mr. Powrie, by the addition of two new Crustaceans, Stylonurus and Campecaris, and by the discovery of parts of the Ichthyolite Cephalaspis Lyellii, and of another fine species, as well as many fish-spines &c. The term 'Tilestones,' for which I have substituted 'Passage-beds,' cannot, therefore, be made to include both the black schists of Lanarkshire (which are unquestionably Upper Silurian) and the Arbroath paving-stones (which must be regarded as the basement-beds of the Old Red).

coarse conglomerates on the sides of the mountain of clay-slate which flanks the Grampians, that these beds formed a passage into the Lower Old Red or Cephalaspis flagstones which undulate over Forfarshire and are surmounted by other red sandstones.

In Banffshire, in 1859, I visited the banks of the Spey, and also Tynet Burn, where, through the kindness of Mr. Alexander Simpson, of Holl, I obtained a collection of fossil Fishes of the genera Pterichthys, Coccosteus, Glyptolepis, Osteolepis, Cheiracanthus, Diplacanthus, &c. As these are forms also known in Caithness, it is interesting to observe that the strata at Tynet lie far above the great mass of lowest Old Red Sandstone; they are, in fact, like the Gamrie Ichthyolites, in the central zone of the group.

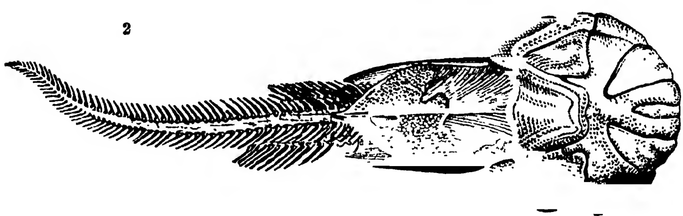
FOSSILS (70). OLD RED SANDSTONE FISHES.

1



1. Underside of Pterichthys cornutus, Agassiz, from Morayshire.
(See the striking description of this Ichthyolite by its discoverer, Hugh Miller, in his 'Old Red Sandstone,' p. 46.)

2



2. Coccosteus decipiens, Agassiz, somewhat restored.
(A perfectly restored head of this Fish is given in Mr. Miller's eloquent work, the 'Footprints of the Creator,' p. 50. Edinburgh, 1850.)

The bituminous flagstones of Caithness and the Orkneys being thus considered the central portion of this geological group, we may endeavour to see if there be any cause which may serve to explain why their imbedded Ichthyolites, so abundant in the north, should be so rare in the central and southern parts of Scotland. The explanation, it seems to me, is given in the fact that, as we proceed from north to south, the bituminous and calcareous schists and flagstones so thin out that already in Nairn and Elgin, and still more at Gamrie, in Banff, such beds are represented by clays with nodules only, and that further southwards even these are no longer traceable in the central portion of the sandstones. The condition, therefore, of

the northern seas of Devonian age, and the sediments therein accumulated, must be considered to have specially favoured the life of certain Fishes, whose remains are not to be detected when we pass into more southern tracts, where such conditions no longer prevailed.

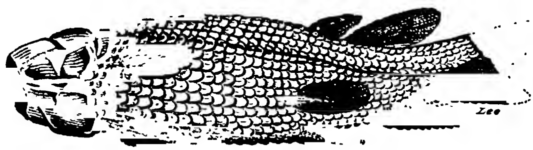
In the central zone of Caithness and Orkney, and its diminished equivalents in Cromarty, Nairn, Elgin, and Banff, are found many species of the following genera of Agassiz, viz. Pterichthys, Coccosteus, Cheiracanthus, Diplacanthus, Cheirolepis, Dipterus, Osteolepis, Diplopterus, and Platygnathus *.

Two of the most peculiar of these forms, Pterichthys (including Pamphractus) and Coccosteus, when first found, appeared so unlike Fishes that all the skill of Agassiz was required to refer them to that class.

Coccosteus decipiens, which is here represented, was first put together with consummate talent by Hugh Miller, from several of its detached fragments which that ingenious philosopher collected on the shore of Cromarty.

The other genera above mentioned have more obvious piscine characters. These characters are apparent even in fragments of those fossils which were first published by Sedgwick and myself from the flagstones of Caithness,—such, for example, as Dipterus and Osteolepis, first described by Cuvier at my own request. Another of these Fishes is here represented.

FOSSILS (71). GANOID FISH OF THE OLD RED SANDSTONE.



Dipterus macrolepidotus, Ag., of the black schists of Caithness. From a specimen in the cabinet of Sir Philip de M. Grey Egerton, Bart.

This figure of a specimen in Sir P. Egerton's cabinet is more correct than that given in my first edition. The extra anal fin supposed to exist in this genus and some allied forms is not seen in this specimen, which shows the ordinary arrangement of a pair of pectoral and a pair of ventral fins, with a single anal fin in advance of the great caudal appendage. Such, no doubt, is the true structure of Dipterus and Diplopterus, which were predaceous Ganoids of the Sauroid family. Their forms, though of great breadth in proportion to their depth (something like that of the Gurnard of our coasts), were compact and graceful.

The breadth and depression of the head in these fishes is well seen in

* These Caithness Fishes were first noticed in 1826, in my memoir on the Coal of Brora in Sutherlandshire, Trans. Geol. Soc., n. s., vol. ii. p. 314; and were afterwards placed in their proper geological position, in 1827, by Professor Sedgwick and myself, Trans. Geol. Soc., 2nd ser., vol. iii. p. 142, pls. 15, 16, 17. They were partially described and named by Cuvier, who compared them with the Lepidosteus.

the subjoined small woodcut, which exhibits the frontal portion of the cranium of Diplopterus borealis *. The jet-like lustre of some of the Caithness and Orkney Ichthyolites and the blackish-purple and dark-blue colours of others, make them very conspicuous objects in the grey flagstone.

FOSSILS (72).
CRANIAL BONE OF DIPLOPTERUS.

Frontal portion of the cranium of Diplopterus borealis. From the dark grey flagstones of Stromness, Orkney.

The central or Caithness flags near Wick have also afforded, to the researches of Mr. C. Peach and others, forms which, resembling shells, have been spoken of as such; but they are now shown by Professor Rupert Jones to be the bivalve carapaces of the Crustacean genus Estheria †. E. membranacea, Pacht, abounds in the flagstones of Caithness, and is plentiful also in the Devonian sandstones of Livonia.

The bituminous schists of the North of Scotland thinning out in their range southwards, the next member of the series in the central parts of Scotland is specially characterized by other Ichthyolites. It is, however, to be observed that the central group of Ichthyolites, which specially characterizes the bituminous flags of Caithness and the Orkney Islands, is found at various places as we proceed southwards along the east coast of Scotland. Thus, at Edderton, in Ross-shire, the Rev. J. M. Joass has discovered in red sandstone a considerable number of the genera. Traces of the same Fishes have been found in the Black Isle; and Hugh Miller has described them from near Cromarty. They are seen at intervals in Inverness-shire, Nairnshire, and Morayshire ‡, and reappear on the banks of the Spey near

* From a specimen found by Dr. Hamilton of Stromness. For the entire cranium see Hugh Miller's Footprints of the Creator, p. 58. He particularly refers to the small central plate in the frontal bone as common to most of the Ganoids of the Old Red.

† Monograph of the Fossil Estheriæ, Palæontograph. Soc. 1862.

‡ Already in 1828 Professor Sedgwick and myself united into one geological group the lower red conglomerate and sandstone, intervening cornstones, and the yellow fish-bearing sandstones of Elgin. We further showed that the fish-bearing zone of Caithness was traceable to the south-east of Inverness as a thin course of shale, though we there detected no Fishes in it. (Trans. Geol. Soc., 2nd ser., vol. iii. pp. 147, 150 *et seq.*)
The remains of Fishes were not discovered until nine or ten years afterwards,—first, I believe, by the zeal of the late Dr. J. Malcolmson. Lady Gordon Cumming, so well known to the readers of the works of Agassiz and Hugh Miller, followed up these researches. Dr. Malcolmson, when on leave of absence from the East Indies, detected several of the Caithness Fishes at Clune and Lethen Bar in Nairnshire; and, having followed up his discoveries into Morayshire, he presented to the Geological Society a detailed memoir descriptive of these tracts in 1839. This paper was to be printed in the Transactions of that Society; but, as the author spoke doubtingly respecting the genera and species of his fossil Fishes, the order for the publication of the memoir was deferred by the Council, until Agassiz, the great authority on Ichthyolites, should have determined the specific characters of those fossils. In the meantime an abstract, giving the main features of the labours of Malcolmson, was published (Proceedings Geol. Soc. Lond. vol. iii. p. 341); and shortly afterwards that accomplished man, having returned to India, fell a victim to his zeal in pursuing geological researches in the jungles of the Bombay Presidency. Subsequently, in 1859, the substance of this memoir, with its illustrative sections, was published in the Edinburgh New Phil. Journal (January, 1859), by the Rev. G. Gordon, and in the Quart. Journ. Geol. Soc. London, vol. xv. p. 336. Dr. Gordon has well illustrated all the fish-bearing strata around Elgin which belong to the Old Red Sandstone, as well as those overlying sandstones which I now refer to the age of the Trias, as will be presently explained.
In mentioning those persons who, in addition to Hugh Miller, Malcolmson, and others, have done such good geological service on the north-east coast of Scotland, I am bound to go as far back even as my own earliest researches of 1826, and to state that my friend Mr. George Anderson, of Inverness, has thrown much light upon parts of his native country, and has been of great use to many an explorer besides myself. Mr. Anderson is well known to all tourists as the author of the 'Guide to the Highlands,' in the third edition of which (pp. 344 to 349 &c.) the reader will find an able summary, by the late Mr. Alex. Robinson, of the Geology of the Moray Firth.

Fochabers, and largely in Tynet Burn, and at Gamrie, on the coast of Aberdeenshire.

In tracing the Old Red group upwards on the eastern flank of the Grampians, from the flags or paving-stones of Arbroath, with their Pterygoti and egg-like bodies, through the Cephalaspis-beds, to the deep-red overlying sandstones of Perthshire (no bituminous schists being there known), we begin to find Holoptychius, a genus which has been continued into the Lower Carboniferous rocks. The species, however, which occur in the deep-red sandstones of Perthshire, and particularly the splendid specimen from Clashbinnie, H. nobilissimus (Pl. XXXVII. f. 9), are entirely distinct from those forms which occur in the highest strata, that are observed to pass up into the Carboniferous rocks.

It is only in certain reddish and yellowish sandstones and shales, as seen in Fifeshire and the Lothians, that the geologist can be said to enter among those strata which here and there are linked on to the Carboniferous rocks above, as they unquestionably are to the Old Red Sandstone below, and which, according to the predominance of their fossil contents, may be grouped with either deposit. Like the strata which connect the Upper Silurian with the Old Red group, these yellow sands and shales are the true transition-beds which unite the Old Red with the Carboniferous series. They are the beds in which the late Dr. John Fleming long ago pointed out the occurrence of Shells and Plants indicative of terrestrial and freshwater conditions *.

Other species of Holoptychius occur both in the red-coloured and yellow sandstones on either coast of the South of Scotland; and, again, some species of this genus, distinct, however, from all those of the Old Red, are found in the lowest Carboniferous strata.

It is worthy of being again noted, that the only scale of a large species of Holoptychius which I met with in preparing the description of the Silurian region was in one of the upper beds of the Old Red of Herefordshire, near Crickhowell, where that formation passes conformably under the Carboniferous Limestone of the South-Welsh coal-field †.

These upper beds are marked at Dura Den in Fife, and at Farlow ‡ in Shropshire, by the presence of Pterichthys, accompanied in the Scotch locality by Holoptychius §. The species, however, are distinct in both cases from those of the older or middle beds in Caithness and the Orkneys, as well as from those of the overlying Carboniferous rocks. Among these

* See Edinburgh Journal of Natural Science, vol. iii.

† See Sil. Syst. p. 171.

‡ See the paper on the yellow sandstones at Farlow by Messrs. Morris and Roberts, Quart. Journ. Geol. Soc. vol. xviii. p. 94.

§ A fine Holoptychius, very nearly akin to the H. nobilissimus of Perthshire, occurs in the uppermost yellow sandstone of Dura Den. My late friend the Rev. John Anderson, D.D. (well known by his work 'The Course of Creation'), detected many well-preserved Ichthyolites in this yellow sandstone of Dura Den. He informed me that the yellow sandstones of Dura Den contain Ichthyolites of the genera Platygnathus, Dipterus, Glyptopomus, Holoptychius, Pterichthys (Pamphractus), with a new genus,—an assemblage which shows that certain genera range from the Caithness flags, or central portion of the Old Red group, up into its highest zone. Dr. Anderson's finest specimens are in the British Museum.

forms, Holoptychius Flemingii and Platygnathus Jamesoni, Ag., are common to the uppermost zone of this group in Scotland and Russia.

I entertain no doubt that these yellow sandstones (with red layers) of Dura Den pertain truly to the Old Red group—that they are entirely subjacent to the adjoining yellow Carboniferous sandstones with Coal Plants. A splendid specimen (now at Rossie Priory) of Holoptychius Andersoni, three feet long, was found on the occasion of a visit I made to Dura Den in company with Lord and Lady Kinnaird and the late Rev. Dr. J. Anderson; and, as a form very similar abounds also in the lower red portions of the deposit (at Clashbinnie), the age of the yellow sandstone of Fife is clearly substantiated.

Some Fishes and certain Plants, of which we shall presently speak, range up from the Caithness beds into the sandstones of the northern headland of Dunnet and the Orkney Islands.

Whilst I adhere to that triple classification of the Old Red Sandstone of the North of Scotland which I correlated with the similar arrangement of the Devonian rocks of Devonshire and the Rhine *, particularly where the series extends from the Ord of Caithness northwards into the Orkney and Shetland Islands, I have to announce that in respect to the age of the uppermost light-coloured sandstones of Burgh Head and Lossie Mouth, south of Elgin and of Tarbet Ness (Ross-shire), I have now abandoned the suggestion of classing them with the Old Red or Devonian rocks. Stratigraphically considered, the strongest grounds indeed still exist to induce the field-geologist to connect these reptiliferous sandstones with the subjacent Old Red Sandstone, on which they repose conformably, as shown in my last edition. In the environs of Elgin I have three times examined these rocks, and on the last two occasions in company with my accomplished friend the Rev. G. Gordon of Birnie, and once when aided by Professor Ramsay. In advancing from the crystalline rocks on the south, and passing through the lower zones of Old Red Sandstone with numerous characteristic Ichthyolites, and from them through the chief yellow sandstones north of Elgin with their peculiar fossil Fishes, into the sandstones of the coast, I could detect no unconformity between all these beds with Ichthyolites and the strata of rather lighter colour, and containing concretionary cornstones, also like Old Red Cornstones, which extend to Burgh Head and Lossie Mouth. It is in these last-mentioned rocks that the remarkable Reptiles the Telerpeton (Mantell), the Stagonolepis † (Agassiz), and the Hyperodapedon (Huxley) have been found.

Again, numerous footprints of Reptiles were found on the surfaces of these sandstones, whether between Burgh Head and Lossie Mouth in Elginshire or near Tarbet Ness in Ross-shire. In the last-mentioned district various geologists have confirmed the original observations of Professor Sedgwick and myself (1827), showing that all these strata seem to

form a natural and conformable cover of the Old Red Sandstone and its Ichthyolites. Professors Ramsay and Harkness have sanctioned this view, as well as the Rev. G. Gordon, the Rev. J. M. Joass, and others who have examined that coast *.

Stratigraphically, therefore, the evidence seemed almost conclusive; and as I had been assured by Professor Huxley that the Reptiles found in these rocks were unique and wholly distinct from any known Mesozoic forms, I was prepared to suggest that, inasmuch as they were purely of terrestrial or fluviatile origin, it might be that creatures of this high organization were in existence when the earliest prolific flora flourished of which we have evidence.

But all such speculation has been set aside by a palæontological discovery which Professor Huxley has made. A fossil Reptilian bone, containing teeth, found in the Keuper Sandstone † at Coten End, south-east of Warwick, was recently brought to him by Mr. Lloyd, F.G.S., of that town. On inspecting this additional relic, Professor Huxley was unable to distinguish it from the corresponding part of the Reptile from the Upper Elgin Sandstone (Lossie Mouth), which he had described and named Hyperodapedon.

To such fossil evidence as this the field-geologist must bow; and instead, therefore, of any longer connecting these reptiliferous sandstones of Elgin and Ross with the Old Red Sandstones beneath them, I willingly adopt the view established by such fossil evidence, and consider that these overlying sandstones and limestones are of Upper Triassic age, and must once have formed the natural base of those Liassic and Oolitic deposits of the north-east coast of Scotland which I described forty years ago ‡.

The accidental conformity of two deposits of very different age is not new to geologists. In Russia, for example, Postpliocene deposits with Arctic shells of existing species are found lying conformably on the surface of horizontal rocks of Carboniferous Limestone; and any elevation of the whole

* See Quart. Journ. Geol. Soc. vol. xix. p. 508, and vol. xx. p. 429.

† This is the formation which my friend the late Hugh Strickland and myself first separated on a map from the underlying Bunter Sandstone, and showed to be the equivalent of the German Keuper (Trans. Geol. Soc. vol. v. p. 331, an. 1837, with map and plate of Fossils and footprints of Reptiles). Several curious Fish-remains, then confided to us by our intelligent friend Dr. Lloyd, were figured as derived from the quarries at Coten End. We also figured footprints of Reptiles observed by ourselves at Shrewley Common, in the Upper Keuper.

‡ 'On the Coal-field of Brora, Sutherlandshire, and some other stratified deposits in the North of Scotland,' Trans. Geol. Soc. Lond., 2nd ser., vol. ii. p. 293. In admitting the value of the decisive evidence of the Hyperodapedon in establishing the Triassic age of the uppermost sandstones and limestones of Morayshire, it is my bounden duty to do justice to Mr. Charles Moore, who in 1859 was the first to recognize fossils of Rhætic age in the shales of Linksfield, near Elgin, and to suggest a Triassic age for the underlying limestone, which I had classed as Upper Old Red Sandstone. This view was communicated to the Meeting of the British Association held that year at Aberdeen, and was supported by Sir Charles Lyell and Professor Nicol. Since then Professor Rupert Jones has corroborated Mr. Moore's view of the Lower Mesozoic age of these Linksfield Shales. (See the Monograph of Fossil Estheriæ, Palæontogr. Soc. 1863, p. 74 &c.) The possibility of the existence of New Red Sandstone or Trias in these northern tracts was suggested by me in the earliest of my memoirs, as above cited. After pointing out the absence of the Carboniferous series in this region, and the difficulty of drawing conclusions from slight differences in the lithological structure between the Old and New Red Sandstones, there is this observation:—"The great fertility of the plains of Easter-Ross (these extend to Tarbet Ness) affords also some slight ground for presuming that this great deposit may be referred to the age of the newer red sandstone." This was written in 1826, before Sedgwick and myself described the Old Red of the Highlands, when we spoke of a sandstone at Loch Greinord, on the west coast, as being of the New Red period. Trans. Geol. Soc., 2nd ser., vol. iii. p. 156.

mass would leave these two deposits of such widely different age in similar apposition*. Some such operation must have taken place when the Old Red Sandstone and its Ichthyolites, lying in an undisturbed and horizontal position, was covered after a long interval by the youngest of the Triassic deposits, and so remained until an elevation took place which raised up the Palæozoic and Mesozoic deposits together to the same angle of inclination, and subjected the whole of these masses to the same flexures, followed, doubtless, in after times by great breaks and denudations.

As I do not profess to describe in this work any Secondary or Tertiary rocks, though they will be alluded to in the concluding Chapter in taking a general view of geological succession, I have withdrawn from this edition the woodcut of the Telerpeton—and the more willingly as a much more perfect specimen of that Reptile has recently been found than that which was figured. I have now only to refer my readers to the complete account of these Elgin Reptiles of the Upper Triassic or Keuper age, which, in completing his former description of them, as partially cited in my last edition, will shortly be given by Professor Huxley in the Memoirs of the Geological Survey of Great Britain.

Plants of the Old Red Sandstone.—The most marked addition, of late years, to the known fossils of the Old Red Sandstone of the North of Scotland, consists of various Plants. Even as late as the year 1854 I could allude to only one unquestionable Land Plant as having been found in this formation, by Hugh Miller, and described by him as a part of a Coniferous Tree†. The same author had afterwards brought to the notice of the British Association for the Advancement of Science, in 1855, several of these fossil Plants, which have since been published in his posthumous work the 'Testimony of the Rocks.' Most of these have been there referred to Tree Ferns, and illustrated in that work by woodcuts ‡.

Living at Wick, in the central portion of the Caithness flags, Mr. Charles Peach laboured incessantly in that locality to discover organic remains, and succeeded in disentangling certain fossil vegetables (as well as many Ichthyolites) from these hard rocks. The Plants are all clearly of terrestrial origin, and are of the same species as those which have been found in the Orkneys by Dr. Hamilton, and at Thurso by Mr. John Miller and the late Mr. Robert Dick §, who have collected many excellent specimens near that town, some of which are figured below.

* See also Dr. Bigsby's suggestive memoir 'On Missing Sedimentary Formations,' in the Quart. Journ. Geol. Soc. vol. xx. p. 198.

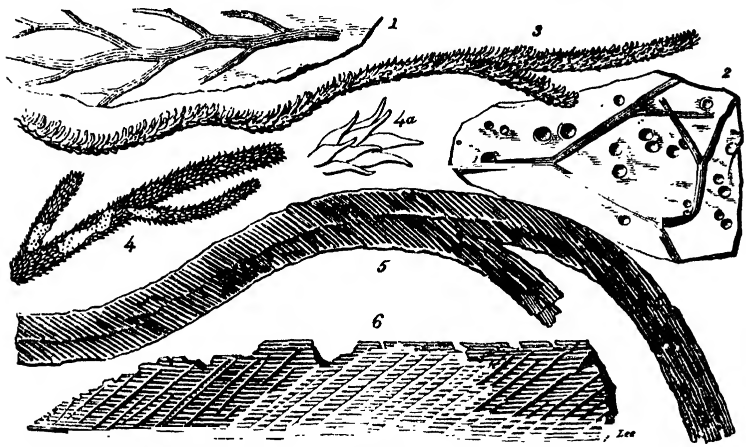
† See 'Footprints of the Creator,' p. 198.

‡ See Miller's 'Testimony of the Rocks,' pp. 24, 432, &c.

§ During my last researches with Mr. Peach, I received, indeed, much valuable information from both of those explorers. Mr. Robert Dick directed my notice to the presence of numerous powerful fractures and dislocations in the flagstones ranging over Caithness, and which to the superficial observer seem to lie simply in undulations. But to whatever extent these dislocations have occurred, they never can be accurately defined until a correct map of the county be executed, it being a melancholy fact that, though very easily capable of examination owing to the slight elevation of the greater part of the county, Caithness is probably the worst-mapped county in Scotland, or rather it possesses no map. Alas! whilst these pages are printing, I have to record the death of this remarkable man. Robert Dick was unquestionably gifted with genius, and possessed of great original strength of mind. That he had a strong poetic verve was proved by his having purchased fine editions of the works of Burns, Scott, Byron, and other poets out of his scanty earnings; for he

The most striking, perhaps, of these fossil Plants are very large, long, flattened bodies, which, from their state of preservation, were clearly woody stems (Foss. 73. f. 6). They were fluted longitudinally, and possessed a central pith. One specimen found by Mr. Peach was several feet in length and 16 inches broad.

FOSSILS (73). PLANTS OF THE OLD RED SANDSTONE OF CAITHNESS.



1. Branched rootlets of some (Lycopodiaceous?) plant. 2. Dichotomous roots (very common) of Lepidodendron?, upon a surface marked with double Annelide-burrows. 3. Lycopodites Milleri, Salter; one-third nat. size. 4. Lepidodendron nothum, Unger?, one-third nat. size. 5. Flattened root, and 6. Fluted stem, of Coniferous Tree; about one-sixth nat. size. [A portion of a Tree-fern (Caulopteris? Peachii, Salter) is figured in the Quart. Journ. Geol. Soc. vol. xv. p. 408.]

Though these plants have often been converted into thin plates of crystalline coaly matter, their forms remain distinct; and under the careful microscopic scrutiny of the late Professor Quekett, they exhibited a true Coniferous structure. In the arrangement and number of the disks upon the fibres they approach near to the Araucarian group. In general appearance, and even in the mode of preservation, they strikingly resemble certain fossil forms from the Upper Devonian rocks of Saalfeld in Germany, collected by M. Richter, and hereafter to be noticed,—such, for instance, as the Aporoxylon of Professor Unger; but this differs in being of simpler structure, and in possessing neither pores nor disks.

These fluted fragments are doubtless stems; and similar but more slender specimens found with them are as clearly the branches, which have borne

was a baker, ever much engaged in hard manual labour. On one of my visits to Thurso, when we were lamenting over the want of a map of Caithness, he prepared for my instruction a model *in flour*, which he manipulated into hills, valleys, and watercourses, and thus brought out in relief all the surrounding country. He was as well acquainted with every living British plant as he was with all the Caithness fossils. Admiring as I did such energy and ability in a modest working man, I rejoice to know that it has been resolved to erect a monument to his memory at Thurso.

Most of Mr. Dick's specimens were communicated to the late Hugh Miller; and, when last in Caithness, I induced Mr. John Miller, of Thurso, to send up all his valuable specimens to London for examination. They have been described by Mr. Salter, in the Quart. Journ. Geol. Soc., Nov. 1857, vol. xiv. p. 72. pl. 5.

whorls of smaller twigs, like their living representatives. Again, large branching woody roots, f. 5, but destitute of superficial markings, appear to have belonged to the same Trees, and are often several feet long. With these occur very many specimens of a Lepidodendron, f. 4, with scaly, short leaves (L. nothum, Unger ?, or a species very like it),—and a Lycopodites, f. 3, with long prostrate stems and secund or one-sided foliage, like that of the common Lycopodium clavatum. This last may of course be of quite a different natural order, and even Coniferous; but its general resemblance alone is implied in the name.

Linear and branched (dichotomous) fragments *, some of them smooth, f. 1, 2, and destitute of all markings, have also been found, whilst others, like them, are covered with small tubercles in quincunx order, and are probably the roots of Lepidodendron, f. 4.

The probability of the smooth forms, f. 1, being also roots is very strong. Similar bodies occur in beds of the Upper Devonian series in North Devon and the South of Ireland, and in such a position with regard to the fluted stems of Knorria, with which they are associated, as to lead to the belief that they are the rootlets of that Plant. The larger ones have even markings similar to those of the main stem.

This probability is strengthened by finding with them similar linear specimens which bear tubercles or excrescences at their tips and along their sides, very like those on the roots of Leguminous Plants and many of the Conifers †. The latter is the more probable analogy.

Hugh Miller has indeed figured a similar fossil ‡ as probably belonging to an ancient marine Plant resembling the Zostera, and has reasonably speculated on the existence of wide fields of such vegetation on the muddy shores of the Old Red period; but our more perfect specimens justify the belief above stated, and as yet there is no evidence of any marine Plant in the Caithness schists. The vegetable remains have evidently been swept from adjacent lands into the sea inhabited by the Fishes above described §.

The flora, on the whole, is analogous to that of the Carboniferous formation, though distinct as to species. In short, there were large Coniferous Trees (with whorls of branches and a structure like that of the Norfolk-Island Pine), Lepidodendron, Lycopodites, and Ferns. That these grew near the coast and were entombed in the shallows of a muddy shore (sometimes in lakes or lagoons, as, perhaps, in the Upper Old Red period) seems proved from their good preservation and from the nature of the matrix, which, moreover, is indented by the burrows of Worms (see f. 2) like those made upon the shores in our own day.

As we advance still higher in the series, or into the strata which overlie

* See also Miller's 'Footprints,' p. 193.

† Dr. J. D. Hooker, Proc. Linn. Soc., No. 58, p. 355*.

‡ Testimony of the Rocks, p. 425.

§ It should also be remembered that Cephalaspis and Pteraspis, both typical 'Old Red' Fish, are found with marine forms at Ludlow.

the Caithness flags, other fossil Plants of large size begin to appear; and several of these have been discovered in the Orkney and Shetland Islands by Dr. Hamilton, which, belonging either to Calamites * or an allied genus (Bornia), make a near approach to forms usually considered characteristic of the Carboniferous era.

Devonian Rocks (*the equivalents of the Old Red Sandstone*) *in Devon and Cornwall.*—The crystalline and slaty condition of many of the stratified deposits in North and South Devon and Cornwall, and their association with eruptive rocks and much metalliferous matter, might well induce the earlier geologists to class them among the very oldest deposits of the British Isles. In truth, the south-western extremity of England presented apparently no regular sedimentary succession by which its grey, slaty schists, marbles, and siliceous grits and sandstones could be connected with any one of the British deposits the age of which was well ascertained. The establishment of the Silurian system, and the proofs it afforded of the entire separation of its fossils from those of the Carboniferous era, was the first step in the inquiries which led to a right understanding of the age of these deposits. The next was the proof obtained by Professor Sedgwick and myself, that the 'culm-measures' of Devon are truly of the age of the Lower Carboniferous period, and that they graduate downwards into some of the slaty rocks of this region. Hence it became manifest that the rocks now under consideration were the immediate precursors of the Coal-deposits, and stand, therefore, clearly in the place of the Old Red Sandstone of other regions. The highly important deduction of Mr. Lonsdale, also, that the fossils of the South-Devon limestones, collected by Mr. Austen and others, really constituted a natural-history group intermediate between those of the Silurian rocks and of the Carboniferous Limestone, was the reason which had most weight with Professor Sedgwick and myself (after correlating North and South Devon) in inducing us to propose the term 'Devonian' †. The stratified rocks of Devonshire and Cornwall, highly varied in composition, and the equivalents of the Old Red Sandstone in the regions alluded to, have also been illustrated by the researches of Sir Henry De la Beche, Mr. R. Godwin-Austen, Professor Phillips, and other geologists ‡.

The most instructive of the sections published by my colleague and myself to illustrate the general structure of Devonshire is that of which the diagram at p. 272 is a reduction §. It passes across North Devon, from the Foreland on the Bristol Channel, to the granitic ridge of Dartmoor on the south, and exhibits a full succession of the Lower, Middle, and

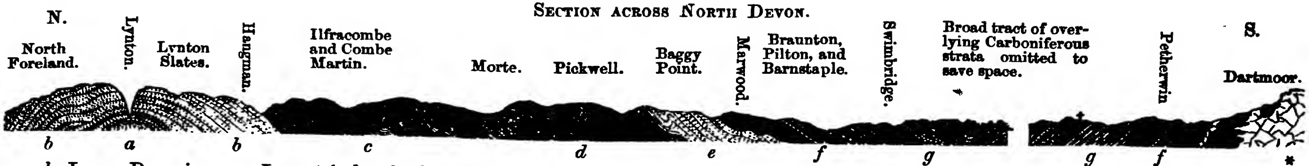
* Dr. Hooker, Quart. Geol. Journ. vol. ix. p. 49; see also vol. xiv. p. 73.

† See Report of the British Association for the Advancement of Science, 1836; Sedgwick and Murchison, Trans. Geol. Soc., 2nd ser., vol. v. p. 633, and Phil. Mag. vol. xi. p. 311. See the memoir of Lonsdale, Trans. Geol. Soc., 2nd ser., vol. v. p. 721, in which our valued friend clearly and modestly states the part which he took in this classification.

‡ See Report on the Geology of Cornwall, Devon, and West Somerset, by De la Beche, 1839, and on the Palæozoic fossils of the same region, by Prof. Phillips, 1841.

§ See Trans. Geol. Soc., 2nd ser., vol. v. pl. 50. figs. 1 & 2.

Section across North Devon.



a, b. Lower Devonian: *a.* Lowest beds of schist and of red and grey micaceous sandstone. *b.* Red sandstone and conglomerate, succeeding the Lynton slates and grits. *c.* Middle Devonian: grey schists and Stringocephalus-limestone. *d, e,* and *f.* Upper Devonian: *d.* Red, grey, and green quartzose schists. *e.* Arenaceous rocks (Baggy, Marwood, and Sloly sandstones), red and brown. *f.* Upper Devonian beds: 1. Upper Devonian at Croyde and Marwood, the equivalents of which at Petherwin comprise the Clymenia-limestone; 2. Passage-beds, at Pilton, Braunton, and Barnstaple. *g.* Trough of culm or coal; a black limestone with Posidonomya near its base, overlain by the grits, schists, and culm-measures of Coddon Hill; the whole representing the Carboniferous series. * Eruptive granite of Dartmoor.

The lowest of these Devonian rocks, *a*, are hard, close-grained, greenish and reddish, siliceous and slightly micaceous sandstones, by no means unlike parts of the Old Red of Pembrokeshire, on the opposite side of the Bristol Channel. Associated with them are chloritic schists, occasionally calcareous, containing Corals, and also Shells, such as Spirifer lævicosta, Sp. hystericus, Sp. canalifer, and Orthis arcuata, usually much distorted by slaty cleavage †. Then follow thick coarser beds, *b*, red and purple, which here and there pass into red conglomerates; whilst some bands are flag-like and spotted, and others are white sandstones. They occasionally contain fragments of the older schists, and many are highly impregnated with red oxide of iron. "Considered as a whole, and from mineral characters, we might compare some parts of this group with the most characteristic portions of the Old Red Sandstone." (Sedgw. and Murch. Trans. Geol. Soc., n. s., vol. v. p. 145.) ‡

These red sandstone and slate rocks, *a, b*, the representatives apparently of the lower shelly 'greywackè' of the Rhine (Coblentz, &c.), are of considerable thickness, and are distinctly overlain on the south by a repetition of red and grey sandstone and gritty series—the Hangman grits, which are succeeded by the Ilfracombe or Middle Devonian slates and their associated limestones, *c*, in which calcareous geodes are frequent, occasionally ranging through some thickness. One band of limestone at Combe Martin is 60 feet thick, and is surmounted by eight or nine other courses, of variable dimensions. They contain remains of Shells, including Stringocephalus Burtini, Rensselæria stringiceps, Streptorhynchus umbraculum, &c., with many Corals known elsewhere, such as Cyathophyllum cæspitosum and Favosites cervicornis.

The calcareous group of Ilfracombe (*c*) is succeeded on the south by hard, slaty, grey, and chloritic schists, without limestone, *d*, but with many veinstones of quartz; these, again, are surmounted by the reddish sandstone and greenish-grey and purplish flagstone of Pickwell Down; and these strike across the country from west to east as far as the Quantocks. Then follow the arenaceous and calcareous flagstones, *e*, of Baggy Point, Croyde, and Marwood, which are much more earthy than the underlying rocks, and contain Cucullæa, Avicula Damnoniensis, Spirifer disjunctus, Strophalosia caperata, and Phacops latifrons, &c., with remains of Land Plants. Here again, even, we have a partial return to the character of the Old Red Sandstone; for the brown and grey flagstones often pass into a red sandstone hardly to be distinguished from the inferior red rock (*a, b*) of Lynton; whilst others are of greenish-grey and brownish sandstone, resembling varieties of the Upper Old Red Sandstone of Scotland. The calcareous group, *f*, of Pilton and Petherwin (on the south side of the culm-trough) completes the Devonian series, and even contains fossils which link it on to the Lower Carboniferous. It is surmounted by true Carboniferous schists, *g*. with the Posidonomya-limestone of Swimbridge and Venn, which is a thin representative of the Carboniferous or Mountain Limestone, and is followed by the Goniatite-grits of Coddon Hill and beds of culm, representing the Millstone-grit series of other parts of England.

† See the able memoir of Mr. D. Sharpe, on the effects of slaty cleavage on the form and outline of several of the Devonian shells, Quart. Journ. Geol. Soc. vol. ii. p. 74.

‡ The same succession of strata (as that described from the North Foreland to Barnstaple) ranges throughout the Quantock Hills, as we learn from the collections made by the late Rev. D. Williams (which are now in the Museum at Taunton) and by sections drawn by Mr. J. D. Pring, late of that town. Favosites polymorpha and Atrypa desquamata are common in the upper or southern portions. I have myself since traced these beds through the Quantock Hills; and recently they have been examined in detail by Mr. Etheridge.

Upper Devonian rocks, from Lynton, through Ilfracombe, to Barnstaple,—the whole dipping under strata of Carboniferous age *, which, on the opposite side of a wide trough, again rise to the surface, resting also upon Upper Devonian strata.

The tract of North Devon has thus been selected as affording the best type of succession of the British rocks to which the name Devonian was applied, because it offers a clear ascending section, through several thousand feet of varied strata, until we reach other overlying rocks, which are undeniably the bottom beds of the true Carboniferous system. For, whether we advance from Barnstaple to the south or from Petherwin to the north (section, p. 272), we find ourselves in a wide † trough of overlying strata in which the slaty character is but little developed, and which are much softer, in places, than those of the flanking tracts.

Now, although this overlying series is in mineral aspect as much unlike the Carboniferous strata of most other parts of Britain as the rocks of North Devon are unlike the ordinary Old Red Sandstone of England and Scotland, we have proofs by fossils, besides the analogy with Pembrokeshire before spoken of, that the black limestones of Swimbridge and Venn &c. with Posidonomyæ (or the calcareous band *g* of the section) do represent, on a miniature scale, a part of the Mountain or Carboniferous Limestone, that the next series of white grit and sandstone of Coddon Hill &c. stands in the place of the Millstone-grit, and that the overlying courses of culm with many remains of Plants are consequently the equivalents of some of the lower coal-bearing strata of other tracts to be described in the next Chapter ‡. In short, no one denies that in the Culm series of Devonshire we have the representatives of the Lower Carboniferous strata.

The objections, therefore (which have, however, been only very partially made), to the view taken by Professor Sedgwick and myself, that the Devonian rocks of the foregoing section are the true representatives in time of the great deposits of Old Red Sandstone of other parts, are quite untenable. In truth, the long period which was occupied in developing the enormously thick Old Red deposits of Wales and of large tracts of Scotland and Ireland must have produced equivalent accumulations elsewhere; and the vast slaty series of North Devon immediately underlying the lowest Carboniferous beds occupies precisely the same position as the Old Red Sandstone of England, Scotland, and Ireland. Moreover, as every geologist knows that the crystalline feature of slaty cleavage was impressed upon

* The coal-field, which is bituminous in Monmouth, Glamorgan, and Carmarthen, becomes anthracitic in Pembroke, where the stone-coal series, much disturbed and broken, differs from that of Devon only in being much more productive. Possibly some of the culm-strata of Devon, devoid as they are of any workable coal, may yield bituminous products by the application of heat.

† The thickness of these Lower Carboniferous strata must not be estimated by the breadth which they occupy on a geological map; for, owing to countless convolutions, the very same beds are repeated over and over in the same broad trough: the folds are well exposed near Bude and at other places on the coast (see Trans. Geol. Soc. *loc. cit.*). The bottom beds only of these undulations, or small portions of each side of the culm-trough (*g*), are represented in the section.

‡ Some of the culm-beds of Devon may be considered subordinate to the Millstone-grit; but most of the culm overlies that rock, and is simply the equivalent of the culm of Pembrokeshire, of which hereafter.

these Devonian rocks long after their formation, so must he also admit that the change from the red sand and shale of Hereford, Brecknock, and Carmarthen to the grey shale with much red sandstone in South Devon is by no means abrupt, but resembles the gradual change which begins to take place in Pembroke. Nor is there any difficulty in supposing how, by a less diffusion of iron, and under dissimilar submarine conditions the southern portion of the area of the same sea should have less of the red colour and sandy character than the northern.

But if, on account of lithological differences, some persons should deny that the slaty rocks of Devonshire can be the equivalents of the red sandstone and shale of the Silurian region of Hereford and Shropshire, let it be recollected that this change in lithological structure is by no means more remarkable than the mutation of aspect and character which the next overlying (Carboniferous) formation has also undergone in Devonshire; for in no distant parts of the world do two coal-formations of like age present mineral and zoological characters more entirely unlike each other than do the rich South-Welsh basin of Glamorganshire and the sterile Culm-region of Devonshire, separated only by the Bristol Channel. Such variations of mineral character in these deposits are not unknown in different parts of the world.

The great eruption of the granite of Dartmoor, which affected both the Devonian and Carboniferous strata in contact with it, has so usurped the place of the regular deposits in South Devon that in vain do we look, either there or in Cornwall, for the same clear order as in North Devon, where the three divisions of this group are clearly recognized, viz. the Lowest or Lynton series (Spiriferen-Sandstein, or Système Coblentzine, of the Rhenish Provinces), the Middle or Ilfracombe series (Lenne-Schiefer, and Eifel-Kalk or Stringocephalen-Kalk), and the Upper or Petherwin series (Cypridinen-Schiefer, Clymenien-Kalk, and Verneuilii-Schiefer of the Belgian area). In fact, the derangement in the western portion of South Devon and the adjacent parts of Cornwall is so great that, as already stated, the Lower Silurian rocks are seen to overlie true Devonian rocks! * The metamorphism of some of the schists has, indeed, often given to them the semblance of the oldest primary rocks. It is now ascertained that in North Devon also much contemporaneous eruptive rock (felspathic ashes &c.) has metamorphosed the slates of the Ilfracombe or Middle Devonian series,—especially along the strike of those beds from Combe Martin to Parracombe, and on to Stowey in the Quantocks, and also along another line ranging from Lee Bay west of Ilfracombe to Kentisbury and Rowley, and along a still better-defined course from Woolacombe to West Down, Bittadon, and Garman Down &c.

The Quantock Hills.—These hills of Western Somerset, ranging from S.S.E. to N.N.W., are essentially composed of a great mass of the Lower

* See p. 145, and Quart. Journ. Geol. Soc. vol. viii. p. 13.

Devonian sandy and slaty 'greywackè' rocks, which, dipping to the E.N.E., are overlain, on the lower grounds, by true Middle Devonian limestones, the equivalents (as shown by their fossils, and particularly their Corals) of the Ilfracombe beds of North Devon and the great limestones of South Devon.

The lowest beds visible (nearly if not quite as low in the series as *a* and *b* in the section of the North Foreland, p. 272) are well exposed in a bold escarpment at Triscombe and other places, where the strata consist of a hard greywackè, purplish-red outside, and weathering into irregular fragments. These strata dip to the E.N.E. at an angle varying from 25° to 30°, and are surmounted by others having very much the same lithological character, together with occasional glossy shillat, which, from its irregular fracture, can only be used for wall-stones. The highest point in the range, called Wills Neck, is about 1000 feet above the sea. In advancing from the escarpment across these hills, whether to Asholt or to Adscombe, by the beautiful new roads in the picturesque woody demesne of Lord Taunton, a considerable thickness of these strata is exposed; and on approaching their eastern flank undulations are seen. The most remarkable of these is marked by the presence of a very peculiar green rock, which, ranging with the strike of the formation from S.S.E. to N.N.W., has been extensively quarried by Lord Taunton for the construction of 'Quantock Lodge,' and is the only freestone in the range. This rock is manifestly of igneous origin, and was, I doubt not, formed by a submarine outpouring of volcanic materials (ashes &c.) during the accumulation of the other strata. When quarried in the deepest openings, it is of a grass-green colour and comparatively soft; but when exposed to the atmosphere, it becomes very hard, assumes a somewhat darker tint, and will take a fine polish. The ordinary rocks of the hills fold round this ashy greenstone, as if they had been disturbed; but the strata soon resume their regular dip to the E.N.E., and pass under the limestones which are exposed in various places on the flank of the hills, extending from Asholt to Adscombe, by Nether Stowey, Upper Stowey, &c. Along the line between the greenstone and the limestones, there are copper-ores, which have been worked.

In the northernmost part of the chain, the strata are very highly inclined. The greywackè, in parts purplish red, in parts grey, used for road-making, and well exposed in Sir Peregrine Acland's quarries, dips from 45° to 50° to the E.N.E., and is succeeded on the dip by the fossiliferous limestones of Upper Stowey &c. The only organisms I could detect in the ordinary greywackè of the Quantocks are minute fucoidal bodies.

The overlying limestones (*c* of the section at p. 272) contain many Corals and Encrinites, like those of the Babbicombe and Torquay limestones of South Devon; and Mr. Etheridge, who has examined the localities since my visit, assures me that the identity of the remains from these different

places with those of the Eifel Limestones in the Rhenish Provinces is undoubted.

The disjointed and occasionally inverted masses of South Devon are easily brought into comparison with the clear order of North Devon and West Somerset*. This is in great measure owing to the numerous and well-preserved fossils of its extensive limestones. These are on the parallel of those of Combe Martin and Ilfracombe (*c* of the section at p. 272); and, rising in great masses near Plymouth and Ogwell, they range, with intervals, to Newton Bushel and Torquay†. They are laden with Corals and Shells, many species of which occur in rocks of the same age in North Devon, and also in various parts of the continent of Europe, and notably in the limestones of the Eifel, the Rhenish Provinces, and Belgium. Now many of these fossils are quite peculiar; for, whilst they exhibit an intermediate character (approaching in the lower beds of this series to those of the Silurian system, though almost all distinct, and in the upper strata to those of the Carboniferous era), there can be no doubt that they constitute an independent group.

The species known to occur in the limestone bands of the Middle or Ilfracombe group, stretching from Widmouth through Combe Martin, Twitchin, Simonsbath, Newland, Luckwell, Luxborough, Higher Broadwater, Huish and Nettlecombe, and thence to the Quantocks, are precisely the same as found at Newton Bushel, Plymouth, Ogwell, &c.: they are Heliophyllum Hallii, M.-Edw., Favosites cervicornis, Blainv., Petraia celtica, Lonsd., Cyathophyllum Boloniense, Blainv., C. cæspitosum, Goldf., Hallia Pengellyi, M.-Edw., Cystiphyllum vesiculosum, Goldf., Pleurodictyum problematicum, Goldf., &c., with the Amorphozoan Stromatopora concentrica, Goldf.; and they are accompanied by an equally characteristic series of Middle Devonian Brachiopoda. The Corals have been described in the Memoirs of the Palæontographical Society of 1853 by MM. Milne-Edwards and Jules Haime ‡.

All the species of Trilobites known in the Silurian system have disappeared, and their places are taken by others, of which Bronteus flabellifer, Goldfuss, Phacops granulatus, Münster, P. conophthalmus, Emmrich, P. latifrons, Bronn, and P. laciniatus, Rœmer, are striking types both in Britain and on the Con-

* The differences between the lithological succession in North and South Devon, on the opposite sides of the great granitic axis of Dartmoor, are explained by Sedgwick and myself, Trans. Geol. Soc., 2nd ser., vol. v. pt. 3. p. 635.

† One of the finest collections of the South Devon fossils was made by Mr. R. A. C. Godwin-Austen, whose researches in the field, and whose study of the organic remains, so materially contributed to a correct knowledge of the stratified rocks of Devonshire. See Trans. Geol. Soc., 2nd ser., vol. vi. p. 433; and Lonsdale, ibid. vol. v. p. 721.

In a Memoir on the palæozoic rocks of the Boulonnais (Quart. Journ. Geol. Soc. vol. ix. p. 244), Mr. Austen, like myself, classes the Petherwin and Pilton beds with the Devonian rocks, whilst he separates the South Devon limestones of Newton and Ogwell from those of Ashburton, Bickerton, and Chudleigh. If in this popular work I retain the older view, and group together the South Devon limestones, I would in no respect detract from the value of such a subdivision. My present belief is, indeed, that the lower sandstones, conglomerates, and slates (or the *a b* of the previous section) are truly the equivalents of the Lower Rhenish or Coblentzian shelly greywackè and sandstone—thus completing the parallel between the British and Rhenish Devonian rocks, and giving to each a similar base. In respect to the Upper Devonian division, all foreign geologists who classify by organic remains, including M. de Koninck, whose opinions will be cited in a subsequent Chapter have placed the Clymenia-limestone and the Cypridina-schist in the Devonian system. I must therefore dissent from a proposal of the late Mr. D. Sharpe, to remove these passage-beds to the Carboniferous series.

‡ My friend Mr. Lonsdale does not participate in the opinion of these authors respecting some of the Corals which they refer to the genus Favosites. I earnestly trust that his health will permit him to publish a Report on the Corals from the Palæozoic Formations of New South Wales, transmitted to him by the Rev. W. B. Clark, in which he will assign, I doubt not, valid reasons for the distinctions he draws.

tinent. Large species of Homalonotus (H. Herschelii) &c., different from the Ludlow species, being ornamented with spines, characterize the lowest beds. They are found, too, in Devonian strata of very distant regions, *e. g.* the Cape of Good Hope. Trilobites, however, which swarmed in Silurian times, were comparatively scarce in the Devonian: although several of the very numerous genera of the former era are known in it, no new genera are introduced.

Among the Mollusca, nearly all the species of Atrypa, Orthis, and Spirifer differ from those of the Silurian era*. One shell, however, Atrypa reticularis, must be mentioned as an exception to the prevalent rule of each great group being distinguished by peculiar forms; for this hardy species, with which the reader became familiar in the Silurian rocks (see p. 210), lived on to the Devonian era, and is as common in the limestones and shale of Devonshire as in the older series. It even ranges to the furthest known geographical limits of the Devonian rocks—to Armenia, the Caucasus, and China on the east, and to the Devonian deposits of America on the west!

Although many of the Silurian and Devonian genera are the same, yet the proportional number of species is very different, and certain genera of Shells which were common in the older period are no longer traceable. Thus the genus Orthis becomes far less abundant, whilst Spirifer, comparatively rare in the older rocks, augments much in variety of forms, and especially in the size of the shell—the large broad-winged Spirifers being especially characteristic of rocks of this age, and particularly in the Lower Devonian of several foreign countries. Several species of Brachiopods common in the sandstones of Torquay and Fowey in South Devon and Cornwall are, indeed, well known in the Rhenish Provinces. Such, for example, are Spirifer micropter, Goldf. (Sp. hystericus, Schl.), Sp. lævicosta, Valenc. (Sp. ostiolatus, Schl.), Chonetes sarcinulata, Hupsch (Ch. Hardrensis, Phill.). In Britain, no Brachiopod is more typical than Atrypa desquamata, Sow., Foss. 74. f. 5.

Tentaculites annulatus, Schl., a species of Homalonotus (probably armatus, Burm.) with spines, and the remarkable Rhenish Coral Pleurodictyum problematicum, Goldf., are among the characteristic species of the lowest beds.

As if to draw the parallel even still closer between Devonshire and the Rhine, Bactrites (Orthoceras) gracilis, Münster, the prevailing fossil of the Wissenbach slates (which, as will hereafter be seen, occupy a low position in the series) has been found at Black Head near St. Austel.

The most typical Shells which mark the strata in which they occur as of Middle Devonian age are the large Stringocephalus Burtini, Defrance, Foss. 74. f. 4, Megalodon cucullatus, Sow., f. 2, together with Murchisonia bilineata, Phillips, f. 3 (M. bigranulosa, d'Archiac), and the Corals Cyathophyllum cæspitosum, Goldf., Heliolites porosus, Goldf., and Calceola sandalina, Linn., Foss. 74. f. 1.

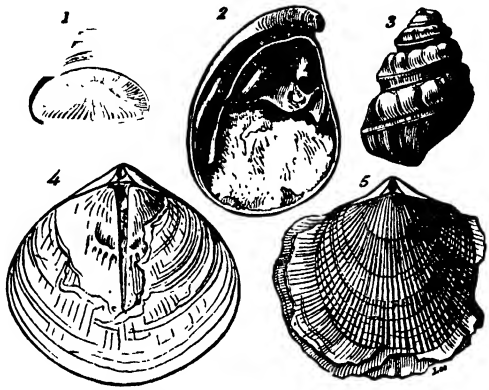
To these few characteristic fossils the following may be added as abounding in the limestones of Plymouth, Berry Head, Teignmouth, Ogwell, and part, at least, of those of Newton Bushel†, viz.:—Spirifer speciosus, Schloth., Cyrtina heteroclyta, Defrance, Pentamerus brevirostris, Phill., Cyrtoceras ornatum, Goldf., &c.; species of Scoliostoma (or Vermetus?), Euomphalus annulatus, Phill., Pleurotomaria, Macrocheilus, Loxonema, Acroculia, and Porcellia; Encrinites

* Many Silurian species appear, indeed, in catalogues of Devonian fossils, but in most cases, it is believed, (with the exception of a few Corals) erroneously.

† The higher beds at Newton Bushel are certainly of newer date, the characteristic Shell being Rhynchonella cuboides, Sow., a species which characterizes the beds immediately below the Clymenia-limestones of Germany and Belgium. A species of Chiton (the elongate form, Helminthochiton) is also found in the Newton Bushel beds.

(Hexacrinus, Platycrinus, &c.); with the Trilobites Bronteus flabellifer, Goldf., Harpes macrocephalus, Goldf., Phacops, &c. The same species are found in the Middle Devonian limestones of Combe Martin and Ilfracombe in North Devon, with also many other equally important Shells characteristic of this stage, viz. Rensselæria stringiceps, Rœmer, Meristella plebeia, Sow., Streptorhynchus umbraculum, &c., associated with the usual and characteristic Corals Heliophyllum Hallii, M.-Edw., Cyathophyllum cæspitosum, Goldf., C. Boloniense, Blainv., Cystiphyllum vesiculosum, Goldf., Hallia Pengellyi, M.-Edw., and Pleurodictyum problematicum, Goldf.

FOSSILS (74). FOSSILS OF THE MIDDLE DEVONIAN LIMESTONES.



1. Calceola* sandalina, Linn. 2. Megalodon cucullatus, Sow. 3. Murchisonia bilineata, Goldf. 4. Stringocephalus Burtini, Def. 5. Atrypa desquamata, Sow.

The curious fossil called Sphæronites tessellatus by Sir H. De la Beche also occurs here. It is not, however, a Cystidean, that family being confined to the Silurian rocks, but is, perhaps, a complex sponge, as is also Steganodictyum of M'Coy, from the slates of Polperro, Cornwall. The fossils of the calcareous slates, indeed, which range throughout the southern parts of Devon and Cornwall, are for the most part the same as those of the limestones—Atrypa desquamata and Phacops laciniatus being the commonest forms at Padstow, Liskeard, and St. Keyne.

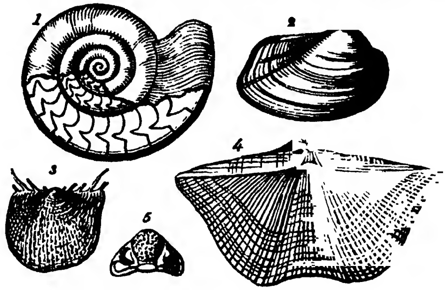
To return to the section, p. 272. The highest rock which is there classed as Devonian (*f*), and which lithologically is an upward continuation of the slaty series, differs very considerably on the two sides of the trough—so much so that there is much difficulty in identifying the beds on the southern side of the trough with those on the northern. On the southern side the strata, by their schistose and calcareous nature, as well as fossils, truly represent the Upper Devonian limestones and schists of Germany, of which mention will be made in a subsequent Chapter; but the beds of the Barnstaple section differ much in lithological character and fossil contents, and indicate, both in my opinion and in that

* This was formerly regarded as a Brachiopodous Shell; but Lindström has shown that it is a Zoophyte belonging to the Actinozoa Rugosa: Geol. Mag. vol. iii. pp. 356, 406.

of Mr. Salter (who reexamined them carefully), a somewhat higher zone in the series, passing insensibly into the Carboniferous group above.

To begin with the beds of Petherwin in Cornwall. Here the uppermost beds, underlying the trough of culm-strata, consist of soft, fissile, grey slate, with some courses of impure limestone, *f*, as expressed in the previous section (p. 272). In this band a great number of fossils have been found; and these, whatever ambiguity may attach to the beds of Barnstaple, clearly identify the Petherwin series with the Upper Devonian of many parts of the continent of Europe. Such are Phacops granulatus, Münst., Foss. 75. f. 5; Clymènia undulata, Münst.,

FOSSILS (75). FOSSILS OF THE UPPER DEVONIAN.



1. Clymenia undulata, Münst. 2. Cucullæa Hardingii, Sow. 3. Strophalosia caperata, Sow. 4. Spirifer disjunctus, Sow. (Verneuilii, Murch.). 5. Phacops granulatus, Münst.

f. 1; C. lævigata, Münst.; C. striata, Münst.; Goniatites subsulcatus, Münst.; Cardiola retrostriata, Von Buch, and Productus subaculeatus, Murch. These fossils are not found in the Barnstaple series. Several species (probably 14 or 15), however, are met with in both localities. Spirifer Urei, for instance, and Orthis interlineata are common fossils; and these, with Spirifer disjunctus (or Verneuilii), a Devonian fossil of the Boulonnais, help to connect these beds with those on the north side of the culm-trough. On the other hand, the characteristic Trilobite Phacops latifrons, Bronn, so common at Barnstaple, is absent from the Petherwin deposits*.

The most typical portion of the Upper Devonian beds of Barnstaple is the calcareous band of Pilton, Brushford, and Braunton, which ranges to the sea at Croyde Bay. Now, whilst the lower sandy strata of this section, as at Marwood and Baggy Point, contain numerous Cucullææ (chiefly C. Hardingii, Sow., Foss. 75. f. 2, and C. trapezium, Sow.), with Avicula Damnoniensis, Sow., Curtonotus, Ctenodonta, Modiola, &c., Bellerophon subglobatus, M'Coy, and a peculiar species like B. trilobatus of the Tilestones (B. bisulcatus of Rœmer), and also casts of Land Plants, such as Knorria dichotoma, Haughton, Adiantites, and a species of Bornia, &c.,—the upper or calcareous part is charged with a true Devonian Trilobite, Phacops latifrons, Bronn, together with species of Pleurotomaria, Orthis, Spirifer, Terebratula, and Strophalosia, some of which occur in the Carboniferous rocks, but others are Upper Devonian. Such are Spirifer Verneuilii, Murch. (Sp. disjunctus, Sow.), and Strophalosia productoides, Murch.

* It is present in a small outlier of slaty rock which pierces the culm a few miles north of Launceston, and is there accompanied by Petraia Celtica. This outlier was observed many years ago by Mr. S. R. Pattison, and has since been reexamined by Mr. Salter, who was unable to obtain satisfactory evidence of its being higher in the series than the Petherwin limestone. He is, however, strongly inclined to that opinion, both from its position and organic contents.

(Str. caperata, Sow.). Productus prælongus, Sow., is a species elsewhere unknown, but occurring in profusion in these beds. With this, too, is a local form, resembling Spirifer cuspidatus, Martin, of the Carboniferous Limestone; and there are fossils of that formation—Spirifer Urei, Flem., and Rhynchonella pleurodon, Phill.,—together with Fenestellæ, Encrinites, Fish palates, &c. which appear to be identical with those of the Carboniferous Slate. Here, again, though with considerable mineral variations, we see the same upward succession as in Scotland and Ireland; and in approaching the summit of what has been classed as Devonian or Old Red, we are gradually introduced to the flora and fauna of the Carboniferous era.

It has been proposed, indeed, to classify this Upper Devonian deposit with the Carboniferous system, that view having at one time been advocated by the late Mr. D. Sharpe and Mr. Godwin-Austen. Mr. Salter and Mr. Etheridge, however, agree with me; and, whilst grouping the upper portion of the Barnstaple band with the Lower Carboniferous Limestone-shale, they regard the Pilton and Marwood strata * as the uppermost part of the Devonian series, and as passing upwards from it into the Petherwin band, which is the true representative, in the Devonian area, of the Upper Old Red Sandstone of Scotland.

This Upper Devonian of South Britain, which occupies, in my opinion, the same place in the geological series as the uppermost Old Red Sandstone flanking the Silurian region, and the sandstones with Fishes and Plants in parts of Scotland, is well represented by the beds of Petherwin (*f* of the section, p. 272), while perhaps a somewhat higher member of the series is included in the Marwood and Barnstaple band.

In addition to Phacops granulatus, Clymeniæ, and other fossils above mentioned, the Petherwin beds are also marked by the presence of a minute Crustacean, Cypridina serratostriata, Sandb., which will be much spoken of in treating of the Upper Devonian rocks of Germany (Chapter XV.). The discovery in Britain of this small Crustacean was made long after the distinguished palæontologists, the Sandbergers, had found it in myriads occupying the upper schistose and calcareous rocks of the Rhine, which Professor Sedgwick and myself had formerly shown to pass immediately under the lowest Carboniferous deposit, and to be the true equivalents of our Upper Devonian rocks. The observation of F. Sandberger (for it was he who first detected this so-called Cypridina in British rock-specimens, sent to him) has therefore been peculiarly valuable, as, by means of this minute but characteristic Crustacean, we now learn conclusively that the limits of the Devonian rocks in South Britain have been correctly defined, their equivalents in Germany being similarly distinguished by fossils.

Devonian Rocks in Ireland.—In describing the Upper Silurian rocks of the Dingle promontory in Ireland, p. 178, a general section was given, with allusions to the labours of Sir R. Griffith, and those of Jukes and

* In the South of Ireland these Marwood beds are, perhaps, represented by the 'Coomhola Grits' of the South of Ireland.

GENERALIZED SUCCESSION OF THE ROCKS IN THE SOUTH-WEST OF IRELAND, FROM THE UPPER SILURIAN ROCKS TO THE CARBONIFEROUS LIMESTONE.

h. Carboniferous or Mountain Limestone. *g.* Carboniferous Slate. *f.* Upper Devonian or Upper Old Red Sandstone. [*e.* Middle Devonian; wanting in Ireland: the Limestones of Devon and the Eifel, and the Caithness Flags of Scotland.] *d.* Lower Devonian, or Glengariff, Killarney, and Dingle slates, schists, and grits. *c.* Silurian Passage-beds. *b* & *a.* Upper Silurian with Ludlow and Wenlock fossils.

Du Noyer of the Irish Geological Survey, to show that the strata containing Wenlock and Ludlow fossils there graduate conformably upwards into a vast thickness of schistose and flaggy purple and greenish sandstones, surmounted by conglomerates. These, from the position they occupy, must represent *in time* the slaty and calcareous Devonian rocks and their equivalent the Old Red Sandstone. The greenish and purple flagstones immediately surmounting the Ludlow rocks, as I assured myself by personal inspection in company with Sir R. Griffith, Mr. Jukes, and Mr. Du Noyer, are followed by a great thickness of those hard, green, quartzose, coarse, gritty rocks, with interlaminated slaty layers, to which the name of 'Glengariff Grits' was at one time assigned. From their hard and semicrystalline character, whether they be examined in the Dingle Peninsula, at Glengariff, or in the lofty mountains (including Macgillycuddy's Reeks) around the Lakes of Killarney, it is little likely that fossils will be detected in them. They often, indeed, assume that aspect which by old geologists would have been designated 'grauwacké' *.

These purple and greenish grits, together with sandstones and conglomerates of considerable thickness (the latter containing rolled fossils of the Upper Silurian rocks), constitute one physical mass. Their lowest part, being welded on to the Upper Silurian by the thin fissile strata above noted, may pass for the tilestones of the Silurian region of England and Wales. The great superior masses can only represent the chief Lower Devonian masses of North Devon and the Quantock Hills, as well as those varieties of the Scottish Old Red Sandstone of Scotland, particularly in Forfarshire, which are grey in colour, conglomeratic, and slaty. In fact, these great masses, regularly superposed as they are to the Upper Silurian, stand precisely in the same place as the lowest Old Red Sandstones near Ludlow, the oldest sandstones and grits of North Devon, the grits and slates of Coblentz and the gorges of the Rhine, and the conglomerates and sandstones of Forfar-

* All these rocks are now named 'Old Red Sandstone' by the Irish Geological Survey, both in Maps and Sections.—January 1867.

shire. In Ireland the Middle Devonian, or the limestone of Devonshire and the Eifel, which, from its fossiliferous structure, gives the dominant character of the system, is wanting, as indicated by the preceding diagram, p. 281; for the lower slaty grits (*d*) are unconformably overlain by sheets of red sandstone (*f*), more or less horizontal, which overlap the edges of the older rock. We have in this fact, the great hiatus which occurs between *d* and *f*, the most decisive proof that the central portion of the Devonian or Old Red system has been omitted in Ireland.

In Ireland the lowest Carboniferous rocks, which are slaty, and are known as the Carboniferous Slates, stand precisely in the same geological position, in reference to the strata beneath and above them, as the Lower Calciferous Sandstone of Scotland, of which Edinburgh is built, and the Lower Limestone-shale of England. They are only mentioned here to indicate their natural position in the general order of succession, and to show how completely I dissent from an opinion recently expressed by Mr. J. B. Jukes, that these Carboniferous Slates of Ireland occupy the lower part of that which is known to be the Devonian formation of North Devon, as already described above. Generalizing from this assumption, Mr. Jukes infers that the great series which all geologists who have examined the tract in the south-west of England call Devonian is nothing but the equivalent of the lowest member of the Carboniferous rocks of Ireland. He therefore infers that the belief of all other geologists in Europe and America must be overthrown, and the so-called Devonian system merged in the Carboniferous as being superior to the Old Red Sandstone *.

The Carboniferous Slates of Ireland, which contain exclusively Carboniferous fossils and no Devonian forms, will be again briefly mentioned in the next Chapter. They have only been here alluded to in defending the truthfulness of the classification adopted, and the true position occupied by the Devonian rocks in the general order of the palæozoic deposits, which has been for the first time impugned by a geologist of repute †, but to whom I reply by indicating that the order of the very rocks in Ireland to which he refers supports the view which I entertain, in common with all my other cotemporaries, as far as I know.

Let me here, also, observe, that on the Continent of Europe there are many large accumulations of similar non-fossiliferous rocks with an equally antique aspect, which occupy the same place in the geological series. Thus, amidst the slaty and siliceous Devonian rocks of Germany, there are vast thicknesses of strata wherein few or no organic remains have yet been detected; their age being only made known by their intermediate place in the series, and rarely by a calcareous fossil-bearing course.

* Mr. Jukes, in his paper on this subject (see Quart. Journ. Geol. Soc. vol. xxii. p. 321), admits that the order of succession in the rocks of North Devon as given by Professor Sedgwick and myself is correct, and therefore is obliged to imagine a great longitudinal fault of gigantic dimensions to reconcile the facts with his own theory. (See p. 276 &c. *ante*, in which it is shown that the decisive Devonian fossils in these rocks are completely subversive of Mr. Jukes's 'Carboniferous' view.)

There can, indeed, be no ambiguity in assigning to these vastly thick Irish rocks (*d* in the section p. 281), immediately and conformably surmounting the uppermost Silurian (*c*), their true stratigraphical place—particularly when we see that they are covered not only by a very full series of the Lower Carboniferous rocks (*g*, *h*), but also by intermediate red conglomerate and sandstone of great thickness (*f*), to which, in Ireland, the term Old Red Sandstone was once exclusively applied.

This is the red conglomerate and sandstone (*h*) of the section, p. 178, which, in one tract, overlaps unconformably different members of the underlying rocks, and is itself conformably overlain by the Carboniferous rocks of the South of Ireland, and forms their natural foundation. Seeing the rupture between it and all that is subjacent, Mr. Jukes and other geologists were at one time led to class this red sandstone and conglomerate with the Lower Carboniferous rocks, including the Yellow Sandstone and Lower Limestone-shale and Slate of Griffith, to which it is conformable; but the characteristic fossils of the superjacent dark-grey and carbonaceous beds, such as Rhynchonella pleurodon and Spirifer cuspidatus, have nowhere been detected in these red strata,—the only remains which might seem to connect them with the overlying Carboniferous strata being certain fragments of Plants apparently common to both, though of these, even, no mutual specific identity has yet been established. It must also be stated that these same beds, particularly in the district of Kiltorkan, contain species of fossils wholly unknown in the Carboniferous rocks. Such are some peculiar Lycopodiaceous plants, the Fern originally called Cyclopteris, now Sphenopteris (or Adiantites) Hibernica, and the large freshwater shell Anodonta Jukesii, Forbes.

FOSSILS (76). FOSSIL PLANT FROM THE YELLOW SANDSTONE OF IRELAND.

Adiantites (Cyclopteris) Hibernica, Forbes, Report Brit. Assoc. 1852.

From specimens in the Museum of the Geological Survey.

The Plant figured here, Foss. 76, was described in 1852 (by Edward Forbes) as the remains of one of the oldest Tree-ferns then known to us, and as essentially distinct from any Plant of the Coal-period.

Again, in these strata the teeth of a Dendrodus and one of the dermal plates of a Coccosteus have also been found, both of them Fishes known in the Old Red or Devonian period only. These beds, like the Upper Old Red Sandstone in many other countries, simply form a natural transition into the Carboniferous system.

I therefore range the uppermost beds of the Old Red Sandstone of Ireland with the upper division of the Old Red of Scotland, which in the north extends into the Orkney and Shetland Islands, and as being also of the same age as the Petherwin beds in Devonshire and the plant-bearing Cypridinen-Schiefer or Uppermost Devonian of Germany—a band which in the two latter countries is united downwards with the other members of the Devonian rocks, and upwards with the Lowest Carboniferous strata.

Recently the maps and sections of the Geological Survey * illustrating the South-west of Ireland have appeared; and in these Mr. Jukes and his assistants have laid down all the above-mentioned rocks which occupy the lofty mountain of Macgillycuddy's Reeks, Mangerton, &c., extending by Kenmare to Glengariff, as that Old Red Sandstone whose base, as before shown, passes down conformably into true Upper Silurian, and is therefore unquestionably Lower Devonian. In truth, these Old Red slaty grits and schists of Ireland have a considerable resemblance to some of the Lower Devonian rocks of the Rhine and North Devon. Now these sections are quite in accordance with the observations made by Professor Phillips and myself (1842), in showing that in their great curvatures these rock-masses, whether consisting of slaty, grey, and purple grits and schists, or of red sandstone, all form one system, the upper part of which passes conformably under troughs of Carboniferous Slate and Limestone, though here and there faults occur at the points of junction. Lying between the Lower Carboniferous strata above and the uppermost Silurian below, these rocks, which are all termed Old Red Sandstone in the newest maps of the Survey, can, therefore, be nothing else than the representatives in time of the Devonian system. Consequently I maintain that the natural sections of the South of Ireland are proofs of the truthfulness of the Devonian classification.

In subsequent chapters we shall see that where the Devonian rocks are much developed in different parts of Europe, and in the Rhenish Provinces especially, they are divisible into three parts as in Scotland and England†. It will further appear how, in other tracts, and particularly in Russia, the Ichthyolites of the Old Red Sandstone of Scotland and the marine Shells of Devonshire, Germany, France, and Spain are found united in the same strata, thus demonstrating the synchronous accumulation of deposits which, although they differ considerably in mineral aspect, occupy precisely the same stratigraphical place in the general series of deposits.

In quitting the consideration of the highly diversified and important group of the Devonian rocks or Old Red Sandstone of the British Isles, it must not be forgotten that, whilst some of its lowest members have

* See the Sheets 173, 183, 184, 191, 192, & 199 of the Geological Survey Map of Ireland. Also the large Sections, pl. 21.

† See the triple division of the Devonian rocks by Sir C. Lyell, Manual of Elementary Geology, 5th edit. p. 424.

rarely afforded traces of Land Plants, its central and upper parts in Shetland, Scotland, Devonshire, and Ireland contain, as in North America, numerous vegetable remains, including Tree-ferns and probably Calamites. We must equally remember that some of these Plants are associated, particularly in Scotland, with the peculiar Ichthyolites of this epoch, and occur in strata which there also rise out from beneath the lowest Carboniferous rocks.

CHAPTER XII.

CARBONIFEROUS ROCKS.

GREAT PRIMEVAL FLORA THE SOURCE OF THE OLD COAL DEPOSITS.—GENERAL VIEW OF THESE DEPOSITS AND THEIR ORGANIC REMAINS IN THE BRITISH ISLES.

ASCENDING in the scale of deposits, we have now reached another grand accumulation of strata, which is not only replete with many types of animal life peculiar to it and unknown in antecedent periods, but is specially characterized by the earliest very abundant remains of a terrestrial vegetation. The reader will remember that feeble traces only of Land Plants have been discovered in the uppermost Silurian rocks. In the Devonian rocks, also, such remains, as before stated, are comparatively rare *, and only abound when we have passed upwards and are surrounded by the spoils of the oldest extensive forests with which we are acquainted.

Now, as these primeval Plants were the substances out of which the great mass of coal has been formed, so we meet for the first time, in mounting up from the basement-rocks, with a profusion of the impressions and casts of Plants in stone. Some idea of the characters of the luxuriant vegetation which must in this age have overspread very wide areas of land, from polar to nearly equatorial latitudes, may be formed by inspecting the annexed woodcut, in which an ideal representation is given of a

IDEAL VIEW OF THE VEGETATION OF THE CARBONIFEROUS ERA.

portion of the earth's surface as clothed with Plants the fragments of which bespeak a rich flora of Vascular Cryptogams, whose fossilized stems and leaves occur frequently in the shale and sandstone of the coal-fields, and, indeed, constitute the coal itself. In the standard work of Bronn, von Meyer, and Göppert, which gives the most complete general tabular

* Though rare in Britain, Land Plants are comparatively numerous in the Devonian rocks of Gaspé and New Brunswick, as will be shown hereafter.

view of ancient nature hitherto published*, Professor Göppert estimates the total number of known species of fossil plants of this great Carboniferous era as 934, which are thus distributed:—

PLANTÆ 879:—*Cellulares*, including the Fungi, Algæ, &c., 13; *Vasculares*, 866; of which 772 are Cryptogamous Plants, or Ferns, Calamites, Asterophyllites; and 94 are Phanerogamous Plants, such as Cycads, Conifers, &c.

The result arrived at by this botanist agrees generally with that of his precursor in this line of inquiry, M. Adolphe Brongniart, who first gave to the world a general and philosophical view of the distribution of former vegetation. On his part Prof. Göppert has not only added considerably to the number of species, but also to the number of coniferous or forest trees†.

Both, however, of these eminent men, as well as many other botanists, are agreed in the opinion that, as the great mass of the Plants belong to the vascular cryptogamic class, the conditions of climate under which such vegetables grew in very various latitudes constituted a phenomenon especially characteristic of the Carboniferous period. These Plants are, in fact, as characteristic of the Carboniferous period as the Trilobites and Graptolites are of the Silurian era. Whilst the earlier system is almost exclusively marked by its marine contents, the Carboniferous deposits owe their chief features to the actual presence or the contiguity of lands covered with a peculiar vegetation, which, disappearing with the youngest Palæozoic strata, now called Permian, was never afterwards reproduced upon the earth; for no one of the floras of subsequent geological periods possessed those characteristic features of rank gigantic Cryptogamia, indicative of a peculiar, warm, moist climate, which so prominently marked the vegetation of the earliest great woody epoch.

In most of their stony characters the successive strata of the Carboniferous rocks do not differ essentially from many which had preceded them. Like the Silurian and Devonian, they contain beds of pebbles or conglomerate, sandstone, shale, and limestone, though they seldom exhibit a true slaty cleavage‡. But, when examined more in detail, they are found to vary considerably in their nature and contents in different parts of the world. In subsequent Chapters a few allusions will be made to these variations in other countries; but for the present we will take a cursory view of some of their features only in Britain.

Lower Carboniferous Rocks of Great Britain.—In the region represented in

* Bronn's Geschichte der Natur, vol. iii. part 2. The so-called 'Transition' plants of Göppert are included in this list, because it has been ascertained that nearly all of them occur in strata which, formerly viewed as ancient 'grauwacké,' are now known to be of no higher antiquity than the lower division of the Carboniferous rocks.

† Geinitz, Dawson, and others have added still further to the known species of Palæozoic vegetation.

‡ In parts of France the Carboniferous rocks are very crystalline and slaty, as I have shown in a memoir on the environs of Vichy: Quart. Journ. Geol. Soc. vol. vii. p. 14. In some of these much dislocated, schistose, and greywackè-like rocks of the Sichon, I obtained specimens of Carboniferous species of Chonetes, Phillipsia, Orthis, Productus, &c., in 1850. In the South of Ireland, also, the Lower Carboniferous strata are slaty.

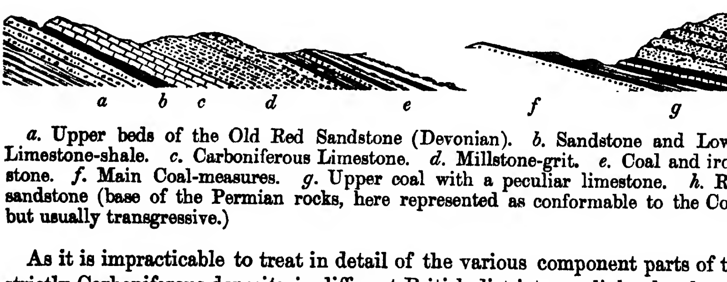
the map annexed to this work, the Carboniferous rocks are most fully develop in the great South-Welsh basin of Carmarthen, Glamorgan, and Monmouth where an ascending order from the summit of the Old Red Sandstone, througl shale, limestone, sandstone, and grits, upwards into an enormously thick coal field, is clearly exhibited in lofty escarpments, particularly around the northern eastern, and western edges of that grand basin. The same succession, though o1 a minor scale, is seen around the smaller basin of the Forest of Dean, and again with certain mineral variations and an expansion of the lower shale, in th county of Pembroke.

Towards the north, the calcareous and lower members of the series are mor developed, as observed in the Oswestry coal-field, and in Shropshire and Flintshire, than in most parts of South Wales. This expansion of the inferior zone of these rocks towards the north becomes still more striking in the range of the strata from Derbyshire into Yorkshire and Northumberland, and particularly in the great central Carboniferous trough of Scotland.

In some of the coal-tracts within or adjacent to the Silurian region, as at Dudley and Wolverhampton, the whole base and central mass of the group, or the Carboniferous Limestone and the Millstone-grit, are wanting, the upper productive measures there reposing at once on Silurian rocks (see woodcut, Sil. Syst. p. 79). In those districts, however, and along the banks of the Severn, good evidences are obtained of the relations of the coal-strata to the overlying red deposits now termed Permian, of which hereafter.

When viewed, therefore, as a whole, particularly in the region of the coloured map, the Carboniferous group (*b* to *g*) may be stated to lie between the subjacent Old Red, *a*, and the red overlying Permian, *h*, thus:—

General Relations of the Carboniferous Rocks in the Central and Southern Parts of England. (See Sil. Syst. p. 79.)



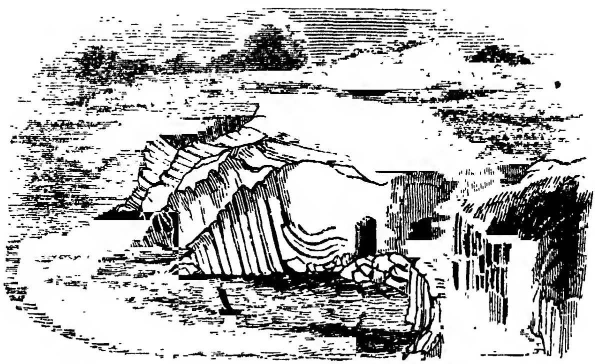
a. Upper beds of the Old Red Sandstone (Devonian). *b.* Sandstone and Lower Limestone-shale. *c.* Carboniferous Limestone. *d.* Millstone-grit. *e.* Coal and ironstone. *f.* Main Coal-measures. *g.* Upper coal with a peculiar limestone. *h.* Red sandstone (base of the Permian rocks, here represented as conformable to the Coal, but usually transgressive.)

As it is impracticable to treat in detail of the various component parts of the strictly Carboniferous deposits in different British districts, a slight sketch only of some of their peculiarities is attempted in the following pages.

Separated from the upper band of the Old Red Sandstone by beds of dark and party-coloured shale (*b* of the section), the Carboniferous or Mountain Limestone, *c*, is the dominant rock of the lower division in the South of England. The massive nature of these calcareous strata and their vast development in Derbyshire, Yorkshire, and Northumberland have long been well known to geologists. Of late years attention has been directed to the still greater expansion of the middle and lower strata in Scotland, where so many beds of excellent coal and much valuable iron-ore are interstratified with various bands of the Carboniferous Limestone, of which hereafter.

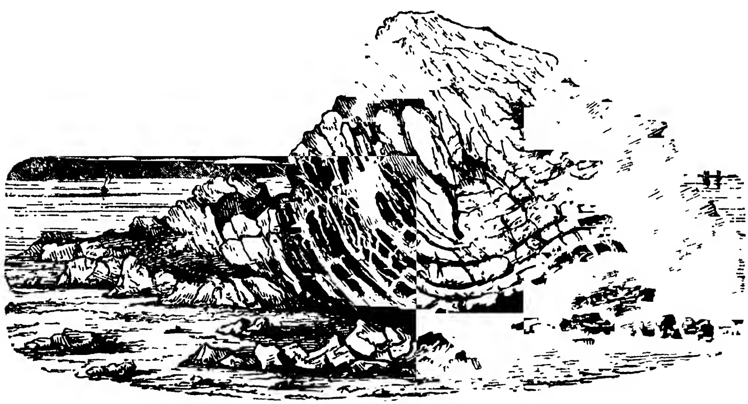
Within the region, however, of the annexed map, this Carboniferous Limestone (2000 feet thick) is of simple and uniform structure, and contains no

coal-seams. Along the rim of the great South-Welsh coal-field, or when traced from Carmarthen into Pembrokeshire, it is exhibited continuously in bold coast-cliffs, particularly in the promontory of Stackpole, where it is much



CLIFFS OF CARBONIFEROUS LIMESTONE NEAR STACKPOLE.
(Sketched by Lady Murchison. From Sil. Syst. p. 382.)

contorted, as in these two sketches. The first of them represents the contortions of the rocks, with their numerous clefts or open masterjoints, which by the power of the waves have been so widened as to form extensive caverns, as seen near Bull-Slaughter Bay. The next is a view of one of the detached folds of the same limestone, known as Stackpole Rock. Though these cliffs seldom



STACKPOLE ROCK *.
(Sketched by Lady Murchison. From Sil. Syst. p. 370.)

exceed 150 feet in height, yet, being precipitous and abrupt, they present a very rugged, wild, and picturesque barrier to the sea, when viewed from the shore—rivalling, indeed, the bold Northumbrian coast-cliffs of the same age, as exhibited between the Rivers Alne and Tweed.

* These striking cliffs are the property of my friend Earl Cawdor, whose chief residence, Stackpole Court, is situated on the Carboniferous Limestone, and whose other Welsh residence, Golden Grove (see the distant edifice in the sketch, p. 54) is on the Llandeilo flags of the Lower Silurian rocks.

Having alluded to the convolutions of the Pembrokeshire limestone, it is right to explain that the violence of the movements which produced them affected still more remarkably all the overlying Carboniferous rocks of that region, and particularly the coal. Thus the latter, which is there nearly all in the state of culm† or anthracite, has been for the most part shivered into small fragments, and is frequently accumulated in little troughs or hollows, the 'slashes' of the miners. Of the great lateral pressure and violent fractures to which the strata have been subjected, the following woodcut may convey some idea.

SLASH OF CULM, IN PEMBROKESHIRE. (From Sil. Syst. p. 377.)

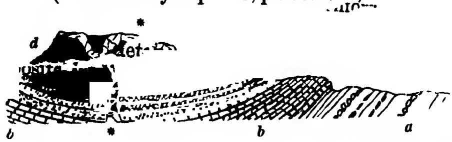
a. Contorted Culm strata, with stone-coal, *a**. *b*. Fault. *c*. 'Slash' of finely triturated culm between violently contorted strata, and probably upon a great line of fracture.

All these convolutions and fractures were produced long after the solidification of the deposits under review.

Whilst the Carboniferous Limestone is separated, as before stated, from the Devonian, or Old Red, by shales (which in Pembrokeshire are in parts both sandy and calcareous), it is there, as in most other districts of England, surmounted by light-coloured sandstones of considerable thickness, known under the name of Millstone-grit.

The English student may, in a small compass, examine the Carboniferous series, from its base upwards to the productive Coal inclusive, on the south-east slope of the Titterstone Clee Hill in Shropshire ‡. Ascending from a depression in the Old Red Sandstone near Cleobury to the eastern summit of that hill, he passes successively over the three divisions of Shale and Limestone, Millstone-grit, and productive Coal,—the whole being capped by basalt, which is seen to have been erupted through the entire series, and to have overflowed on the top of the hill.

SECTION ACROSS THE CORNBROOK COAL-BASIN OF THE CLEE HILLS.
(From Sil. Syst. p. 113, pl. 30. f. 6.)



a. Upper beds of Old Red or Devonian. *b*. Carboniferous Shale and Limestone. *c*. Millstone-grit. *d*. Coal-measures. * Erupted basalt, which has risen through and overflowed the coal.

The Lower Carboniferous members, or the shale, limestone, and grit (*b*, *c*), are, however, of small dimensions in and around the Silurian region, when compared,

† The variations in mineral character of the anthracitic or culm trough of North Devon (doubtless a mere extension of the Pembrokeshire coal-field) have been partially adverted to in the previous Chapter (see p. 271–4, and section, p. 272). One thin course of black limestone with Posidonomyæ is, in North Devon, the true representative of the massive, white, calcareous cliffs of the opposite coast of Pembroke, and of the diversified North British series: so much for great mineral changes, within a few miles, of the same rocks in our own isles!

‡ Any one who is desirous of understanding the peculiarities of this coal-field may refer to the 'Silurian System,' p. 113, where the proofs of the existence of a vertical mass of basalt rising up through the strata are explained, as well as the extraction of coal by shafts from beneath the overlying table of basalt.

I repeat, with their representatives in Derbyshire, the north of England, and particularly in Scotland, where they swell out into a vastly thicker series. In Pembrokeshire, also, these Lower Carboniferous rocks expand to some extent and begin to assume the Irish type. They contain Fishes (Palæoniscus, Psammodus, &c.), with marine Shells, at their base. In the north-western parts of Lancashire and Yorkshire, also, as described by Prof. J. Phillips, those strata consist, in ascending order, of the Great Scar Limestone, estimated to vary in thickness from 500 to 1000 feet,—followed, in the west of Yorkshire, by considerable alternations of shale and limestone, called by Professor Phillips the 'Yoredale Series,' and considered by him to be about 1000 feet thick; while the whole is surmounted by 800 feet of Millstone-grit *.

North-Northumbrian and Scottish Coal.—Besides its grand protrusions of basalt and greenstone, the coast of Northumberland and South Berwickshire exhibits these Lower Carboniferous Limestones, much intruded upon by igneous greenstones and basalts, and opening out into different courses and interlaced by copious masses of schist and several coal-seams. One of the calcareous bands, near the centre of the group, is especially characterized by the Posidonomya Becheri of Bronn. Now it is to be specially noticed that it is through this striking species (which occurs also in the 'Calp' of Ireland) that the thin beds of black Culm Limestone in Devonshire, wherein it also occurs, are known to be of this age (see section, p. 272). This fossil is, further, of frequent occurrence in the schists and 'Kiesel-Schiefer' of the Rhenish Provinces of Prussia, both with and without limestone, and is therefore a good type of the Lower Carboniferous age. It was by such proofs, and by the order of the strata, that Professor Sedgwick and myself showed how the Rhenish schists with Posidonomyæ were the exact equivalents of the British Carboniferous or Culm Limestone of Devon, and how the sandstone which overlies them (the 'Jüngere Grauwacké,' or 'Flötzleerer Sandstein' of the Germans) is the representative of the British Millstone-grit †.

Ascending from the uppermost Old Red (occasionally a yellowish sandstone characterized by the Holoptychius Andersoni and Pterichthys hydrocephalus of Agassiz), the Lowest Carboniferous beds, as seen in the counties of Haddington, Edinburgh, and Fife, consist of a very thick series of sandstones and shale (laden with the remains of Plants), and occasional courses of limestone, to the lower mass of which that sound geologist Mr. Charles Maclaren ‡ assigned the general name of 'Calciferous Sandstones.' In the environs of the Scottish metropolis, the Lowest Carboniferous zone ranges from near Portobello, on the east, to Linlithgow, on the west, the city of Edinburgh being entirely built of its excellent freestone. It also contains thin layers of coal, though the mineral is rarely of sufficient value to be worked. The upper portion of this lowest member, particularly in Edinburghshire and Fifeshire, exhibits those courses of limestone (one of the thickest masses known being at Burdie House) the beds of which are charged with numerous fossil Fishes, such as Holoptychius Hibberti, Palæoniscus Robisoni, Pygopterus Bucklandi, Eurynotus crenatus, Megalichthys Hibberti, &c. Some fossils of this band, including the Unio-like shells called Anthracosia, with dwarf Leperditiæ, indicate the deposit as having been formed

* See the memoirs of Professor Sedgwick, 'On the General Structure of the Cumbrian Mountains,' and 'On the Carboniferous Chain from Penyghent to Kirkby Stephen' (Trans. Geol. Soc., n. s., vol. iv. pp. 47 *et seq.*); also Phillips, Geology of Yorkshire, vol. ii., a most valuable monograph of the native county of the distinguished author. For a most instructive and trustworthy account of the Yoredale rocks and Millstone-grit of North Staffordshire, Derbyshire, Cheshire, and Lancashire the student is referred to Messrs. Hull and Green's memoir in the Quart. Journ. Geol. Soc. vol. xx. p. 242.

† See Trans. Geol. Soc., n. s., vol. vi. p. 228 *et seq.*

‡ Geology of Fife and the Lothians, 1839.

in brackish-water bays or estuaries, in which large and predaceous Sauroid Fishes prevailed.

The next zone, in ascending order, and in which lie some of the most productive coal-fields of Scotland, is, on the contrary, one of purely marine character, in respect to its fossil-bearing limestones, since all these calcareous beds, which alternate with coal, shale, and sandstone, are charged with the Sea-shells of the Mountain or Carboniferous Limestone; for, as all these limestones (of which the Government Geologists Messrs. Howell and Geikie * have mapped eight distinct beds in Mid- and East Lothian) are laden with well-known Producti, Bellerophons, Orthoceratites, and other Mountain-limestone types, the true geological horizon of this part of the great Scottish coal-field is absolutely determined, being manifestly older than the chief productive overlying coal-fields of England.

A general conception of the most productive Scottish coal-fields may be gleaned from an inspection of the section (p. 161) representing the order of the geological series in the western parts of Lanarkshire †. There, in proceeding upwards from the Upper Silurian rocks and Old Red Sandstone, the succession is admirably exposed on the sides of the brooks which descend from the higher moorlands. In these ravines the student sees, exposed to day, the manner in which several bands of limestone, charged with Producti and various other fossils, alternate with shales replete with Plants, and seams of coal, as well as with courses of the celebrated carbonaceous iron-ore known as the 'Black Band' ‡.

In the border tracts between England and Scotland we have yet to ascertain the extent to which the Coal-field of Canoby in Cumberland may be prolonged under the red sandstones, breccias, and conglomerates of Permian age in Dumfriesshire. In Ayrshire, indeed, from beneath those red Permian sandstones which will subsequently be described, there rises a true Upper Coal-field, with the underlying limestones and sandstones. Again, in the basin of the Clyde, as well as in the Dalkeith and Fife Coal-fields, the same upper series is separated from the older zone of the limestones by a representative of the Millstone-grit, on which it rests.

Mr. Geikie has favoured me with the following description of the Carboniferous series in the parts of Scotland which he has surveyed :—

"In Berwickshire, and northwards through East Lothian to the Ochil Hills, the upper red and yellow members of the Old Red Sandstone are found to graduate upward into the base of the Carboniferous series. In the western districts of Scotland, on the contrary, that series seems, at least in wide areas, to have no determinate base, but to lie unconformably on older formations. Arranged in descending order, the following tabular grouping of the Scottish Carboniferous rocks has been made out:—

* As Director-General of the Geological Survey of the British Isles, it is my duty to explain that the boundaries, subdivisions, and details of the Carboniferous masses, and their relations to Silurian, Old Red, and igneous rocks in the counties of Edinburgh, Haddington, and Fife, or around the Scottish metropolis, were first defined upon the six-inch maps, and are now published on the usual one-inch scale. The Officers of the Geological Survey have delineated with precision the relations of all the trappean or igneous rocks, so rife in that region of Scotland, whether they be the great contemporaneous felspathic agglomerates and felstones which are splendidly exhibited in the coast-cliffs between North Berwick and Dunbar, or the numerous rocks of greenstone and basalt which, in the Lothians or in Fife, have been subsequently intruded among the Carboniferous strata. The reader who desires to understand how these igneous operations have been in play during recent geological times should consult a section drawn by Mr. Geikie across the well-known hill of Arthur's Seat at Edinburgh, as published at the foot of the Geological Map of Scotland by that author and myself. Even whilst I write, Mr. Geikie is about to show that the last great eruption of igneous rocks in Scotland took place after the formation of the Middle Tertiary or Miocene deposits. In 1858 the Rev. T. Brown transmitted to me a valuable detailed section along the south coast of Fife, showing the vast thickness of the inferior series of sandstones and shale with eight calcareous courses and five beds of the ordinary Carboniferous or Productus limestone, the whole being in great undulations, with many protrusions of igneous rock. The details are published in the Quart. Journ. Geol. Soc. vol. xv. p. 59.

† See also Page's Advanced Text-Book of Geology, p. 137.

‡ See my memoir 'On the Silurian and Lower Carboniferous Rocks of Lesmahago,' in the Journal of the Geological Society, vol. xii. p. 15, &c.

Coal-measures.	5.	Red sandstones and sandy marls, with Carboniferous Plants in some places, and in Ayrshire with a band of limestone containing Spirorbis carbonarius.
	4.	Upper Coal-measures—a series of sandstones, shales, ironstones, and coals, with Anthracosia &c.
Mill-stone-grit.	3.	Moor-rock—a group of white or grey sandstones, generally persistent throughout the Coal-fields, and believed to represent the Millstone-grit.
Carboniferous Limestone series.	2.	A group of sandstones, shales, coals, and ironstones, with bands of Encrinital limestone chiefly at the top and bottom.
Calciferous Sandstone series.	1.	Sandstones, argillaceous and bituminous shales, a few thin coals, bands of Entomostracan limestone, and courses of shale or marl and cement-stone: known as the "Calciferous Sandstones."

"1. At the base of the series lies a group of strata which present considerable diversities of character as they are traced across the country. In Berwickshire they occur as a thick series of rapid alternations of greenish, reddish, and grey sandy marls or shales, with bands of sandstone and cement-stone. In the east part of East Lothian the marls and cements give place to yellow sandstone and dark shales, with even two or three thin coals. The same character marks the strata as they advance into Mid-Lothian, while it becomes especially conspicuous in the western parts of that county and in West Lothian, where the bituminous shales are now largely worked for oil. In this group of rocks the well-known sandstones of Craigleith and the limestone of Burdie House occur. Ganoid Fishes of the genera Holoptychius, Rhizodus, Megalichthys, Palæoniscus, Amblypterus, &c., with Schizodus, Edmondia, and other Shells, various Entomostraca, and Plants such as Sphenopteris, Lepidodendron, Stigmaria, &c., are among the most marked fossils. In the east of Fife the organic remains have a markedly marine character, consisting of Crinoids, Echinoids, Brachiopods, &c. In the western districts, from the Campsie Hills to the south of Ayrshire, the Berwickshire phase of this series reappears; and we there find a group of thin-bedded, green, red, and grey sandy marls and cement-bands, the whole series being sometimes, as in Ayrshire, remarkably inconstant.

"This lowest group of the Scottish Carboniferous series is marked by abundant evidence of contemporaneous volcanic action, both on the east and west sides of the kingdom.

"2. The *Carboniferous Limestone* series differs from that of the typical English districts, inasmuch as its limestone is confined to only a few bands, which appear chiefly in the upper and under parts of the group, the intermediate space being occupied by sandstones, shales, coals, &c., of the usual Coal-measure type. In Mid-Lothian this series is 1590 feet thick, and contains six limestone bands and fourteen workable coals. In the south part of Ayrshire the thickness is about 350 feet, there being several workable seams in the Dalmellington district, and in the Dailly coal-field seven seams, having a total thickness of 45 feet of coal.

"The fossils of this group are of the usual Carboniferous Limestone types, with the addition of a large assemblage of Carboniferous Plants.

"Contemporaneous volcanic rocks abound in this series. They are especially conspicuous in the Lothians and Fife, where they consist of sheets of basalt and doleritic trap, with ash and ashy beds.

"3. *Moor-rock.*—This group of white sandstones and grits is well seen in Lanarkshire and Linlithgowshire. It occurs likewise in the Lothians and Fife, and appears also to run, though in a less marked development, to the south of Ayrshire. These

strata lie between the Lower and the Upper Coals, and may represent the English Millstone-grit.

"4. *Upper Coals.*—These occur in a thick series of sandstones, shales, fireclays, &c. like those of the Lower Coal Group. It is this upper series which forms the greater part of the coal-field of Ayrshire, and of that which stretches from Glasgow to Bathgate. It occupies likewise the centre of the Mid-Lothian coal-field, and crosses the Firth of Forth into Fife. The fossils of this series of strata are chiefly Plants, with Shells of the genera Anthracosia, Myalina, &c., scales, spines, &c. of Rhizodus, Megalichthys, Ctenacanthus, &c., bones of Anthracosaurus &c.

"Contemporaneous volcanic rocks have not yet been clearly detected in this group; but in Ayrshire it is pierced with necks and bosses of felspathic trap and ash of Permian age; and both in that county and in other districts it is cut through by dykes and masses of dolerite, which are, at least in part, of Tertiary age.

"5. *Red Sandstones and Marls.*—These overlie the Upper Coals in Ayrshire, Lanarkshire, Fife, and Mid-Lothian. For the most part they are barren of organic remains, though in some of the argillaceous beds Carboniferous Plants occur, while in Ayrshire a seam of limestone near the top of the series contains Spirorbis carbonarius. In Ayrshire these red sandstones sometimes rest directly upon the Carboniferous Limestone, so that they are not always conformable to the rest of the Carboniferous formation below. In the same county they are overlain by the Permian sandstones and volcanic rocks."

Lower Carboniferous Rocks in Ireland.—In no portion of Europe, except Russia, are the Lower Carboniferous rocks more widely extended than in Ireland, and at the same time so little productive of coal. This is doubtless in some measure due to the fact that by far the greater portion of the Irish series pertains to the Lower Carboniferous division, which, though it is in Scotland, as above stated, very rich in coal and iron, exhibits no such qualities in those parts of England which lie in the same parallels of latitude as the mass of the Irish rocks of this age. Exclusive of the strata that are separated as being of Old Red or Devonian age (see p. 283), the 'Yellow Sandstone' of Griffith, so defined where it is interstratified with limestone and shale containing Carboniferous fossils with Stigmariæ, as in Scotland, is the oldest member of the system. This is followed upwards by schists, which assume a true slaty structure, particularly in the Cork district, and alternate with courses of limestone. The middle portion is composed of the great Lower Limestone, followed by the dark-grey earthy limestone known under the name of 'Calp;' whilst the 'Upper Limestone' of the midland and southern districts of Ireland is covered by the 'Millstone-grit' with a little coal.

Reposing conformably upon the Upper Red Sandstone described in the last Chapter (see general section at p. 281), this great succession of sandstone, limestone, and shale, the last occasionally affected by a slaty cleavage, is seldom, indeed, seen in one clear and consecutive section. Carboniferous Slates, forming the lowest part of the Irish series, are abundantly displayed on the coasts of the County of Cork, where their relations to the inferior and superior strata are very clear, and were long ago satisfactorily pointed out by Sir Richard Griffith, and have since been described in detail by Mr. Jukes. I have shown in the previous Chapter how these Carboniferous Slates overlie everything to which the term 'Devonian' has been applied. The fossils of the slates are all truly Carboniferous, resembling those of the lowest Carboniferous zone near Barnstaple in Devonshire, and are clearly separable, as proved by Messrs. Salter and Etheridge, from the characteristic types of Upper Devonian age. It is, however, to be noted that these Irish Carboniferous Slates so much resemble rocks of older age in their lithological conformation and oblique cleavage, that, but for the

difference of their fossils and their place in the order of the deposits, they might be mistaken. It is the strong lithological resemblance which led Mr. Jukes to compare with them the lowest slaty rocks of Devonshire, which, containing very different fossils, stand, in my opinion, precisely in the same position as that in which Sedgwick, De la Beche, and Phillips, as well as myself, have placed them. (See above, pp. 282 & 284). Undulating over very wide areas, the Carboniferous Limestone is usually much obscured by gravel, shingle, and clay. Even when the limestones form natural escarpments, they exhibit no seams of coal worthy of notice—as, for example, on the south bank of Lough Erne, and in the hills near Florence Court to the south of Enniskillen, where they exhibit a splendid succession and contain numerous fossils, including large Producti in the lower, and Posidonomyæ in the higher strata. In the Cork district, indeed (where the lower schists are so slaty and crystalline that lithologically they resemble much older rocks), a little coal of slight value has been found—a very feeble representative of the great Scotch coal-deposits of similar age.

The limestone series of Ireland is proved to be of exclusively marine origin, from the multitude of well-preserved fossils it contains; and of these Sir Richard Griffith (with the assistance of Professor M'Coy) some time ago prepared a description of about 500 species *, some of which are stated to be identical with those of the Devonian rocks, but altogether different from those of the Silurian system. These lower members of the system constitute, as before stated, by far the larger portion of all that is Carboniferous in Ireland, and are surmounted (but very partially) by grits and sandstones, in which, at four localities (Kilkenny in the south, and Ballycastle, Dungannon, and Coal Island in the north), a few thin beds of coal are situated; but as, with the exception of the Kilkenny coal-field, they are of comparatively slight and only local value, and have no special bearing on the object of this work, I refrain from saying more respecting them.

The Lower Carboniferous strata hitherto spoken of (or the sandstones, shales, limestones, and grits) are, all over Europe and North America, for the most part of marine origin. The arenaceous and schistose lower strata have, indeed, strong mineral and zoological affinities to the upper portion of the underlying Devonian rocks, into which they graduate. On the whole, however, and notably in its great central masses, this lower division is distinguished from the Devonian by its chief animal remains (including certain genera of Fishes), and, above all, by the intermixture of many more terrestrial Plants than are known in any beds of the preceding epoch. With repeated evidences of thin seams of coal being intercalated with bands of limestone of exclusively marine or estuary character, it is indeed a fair inference that much of the vegetable matter out of which such Lower Coal was formed had been often transported in large matted masses from the mouths of great rivers, or drifted from the shores of broad jungles, into the adjacent seas, and so became commingled with marine remains.

Upper Carboniferous series, or productive Coal-fields of England and Wales.—When we examine the nature of the great overlying coal-strata, an order of things is opened out to us to a great extent different from that which prevailed during the formation of the Lower Carboniferous rocks.

If, indeed, we turn to Germany and France, we see a general physical phenomenon sufficient to explain the change from marine to prevailing terrestrial conditions. In those countries the Lower Carboniferous strata had been dislocated and inclined before the Upper Coal-deposits began to be accumulated on their

* A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland, 1844.

edges; and hence we can apply to the latter a physical explanation of their method of formation which is quite inapplicable to the former. In short, the origin of coal in the younger of these accumulations may be very well accounted for by the depression of low woodlands and jungles beneath fresh water, followed by subsequent elevations and depressions—phenomena which cannot be admitted into our reasoning so long as we refer to the marine conditions which prevailed in the older Carboniferous era, many of the strata of which must have been accumulated in deep seas.

In Britain, however, there is no such abrupt severance in the middle of this natural series; and yet we there see the same changes from marine or estuary conditions to a terrestrial state as in those regions which have undergone a great physical disturbance. Thus, in the thick overlying Coal-measures of Newcastle and Durham, we lose all traces of marine life, and can recognize only huge accumulations of lacustrine or fluviatile origin. In South Wales, on the contrary, where the Coal-measures are estimated to attain the great thickness of 12,000 feet, and one hundred coal-beds are, it is said, intercalated at various levels, we have undeniable evidence of alternating marine conditions *. At the same time, each of these coal-seams has immediately beneath it a band of clay or sandy shale, called 'under-clay,' abounding in Stigmaria, or roots of Sigillaria, one of the plants from which coal has been generated. For this last important fact science is chiefly indebted to Sir William Logan, who, when assisting Sir H. De la Beche in mapping the South-Welsh Coal-basin, demonstrated that the 'under-clay' of the miner had been the soil of a primeval marsh or jungle. (See also Mammat's 'Geological Facts,' &c. 1834, p. 73.) The woodcut in the beginning of the Chapter is intended to convey a general idea of the nature of the wet and swampy tracts in which the vegetation of this period flourished.

The comparative rarity of true dicotyledons or forest-trees in this flora, due perhaps in part to the rapid decomposition of vegetable bodies in a moist warm climate †, is as remarkable as the extraordinary uniformity in the families of Plants of which it was composed. These consisted chiefly, as before said, of Lepidodendra, Sigillariæ, Calamitaceæ, and Ferns, with some curious extinct Pine-trees, some of which resembled the living Araucaria of Norfolk Island. As many of these are found in the roof of the coal, and even in the coal itself ‡, there can be no doubt that, in most of these cases, the mineral resulted from the decomposition and fossilization of the Plants which grew in extensive marshy jungles. It may fairly be inferred that this conversion of vegetables into coal took place at a period in the formation of the crust of the earth when very different physical conditions prevailed, and when a warmer and more equable (though probably not a hot) climate pervaded our islands, as well as latitudes far to the north and south of them. The view which supposes many and successive subsidences of vast swampy jungles beneath the level of the waters best explains how the different vegetable masses became so covered by beds of sand and mud as to form the sandstone and shale of such coal-fields. The theory of oscillation, however, or of the subsidence *en masse* of ancient marshes and their

* Marine Shells have been found associated with some of the lowest beds of coal which have been worked in the South-Welsh Coal-field; Bevan, British Assoc. Report, Trans. Sect. 1858. See also Mr. Salter's appendix to the 'Iron-ores of South Wales,' Geol. Surv. Memoirs, 1861.

† See Hawkshaw, Proc. Geol. Soc. vol. iii. p. 269. The reader will also do well to consult Prof. Lindley's notice of his experiments in decomposing vegetable bodies (see Lindley and Hutton's 'Fossil Flora of Great Britain,' vol. iii. pp. 1-12).

‡ Few persons, who are attentive observers of the fuel they consume, will have failed to detect the forms of plants in the coal itself. Göppert has, indeed, demonstrated, by microscopic examination (and Witham in part anticipated him, 'Observations on Fossil Vegetables,' 1833), that the vegetable fibres and tissues of all the families of the plants of this era are to be detected in the coal itself. In some layers all the plants are Sigillariæ, in others Calamites, in others Ferns. (Quart. Journ. Geol. Soc. vol. v. part 2, Mem. p. 17.)

probable reelevation (with occasional sand-drifts), though good in such examples as those of the South-Welsh and Newcastle coal-fields in England, as also of the large coal-fields in British North America, to which Sir C. Lyell has called attention *, can scarcely have an application to those other seams of coal which, as before mentioned, are interstratified with beds containing marine shells, the animals of which, such as Producti and Spirifers, must have lived in comparatively deep sea-water †.

In such examples (and many of the older coal-beds come into the category) we may, on the contrary, endeavour to explain the facts by the supposition that ancient streams, like the present Mississippi and other large rivers, which flowed through forests on low lands and mud-banks, transported great quantities of trees, leaves, and roots entangled in earth, and deposited them at the bottom of adjacent estuaries, or that these heaps of vegetable matter were carried as floating masses into the open sea.

The coasts of Northumberland and Berwickshire, as well as the large tracts of Scotland already alluded to, exhibit fine proofs of such conditions. The coal-field of the Donetz in Southern Russia, between the Don and the Dnieper, was described by myself and associates as a striking example of similar relations. There, as in Scotland, (besides numerous beds of shale and sand with remains of Plants) bands of limestone, charged with species of Productus, Spirifer, Bellerophon, Nautilus, and other marine Shells, and many Corals, alternate several times with grits, sand, and shale charged with coal ‡ and filled with casts of terrestrial Plants, including Ferns, Sigillaria, Lepidodendron, Calamites, &c. §

General Observations on the Organic Remains of the Carboniferous Rocks.—In treating of the general physical relations of the Carboniferous rocks of the British Isles, and of some changes which they have undergone beyond the region of the annexed map, it has been stated that in the South of Scotland, with the exception of the lowest strata, which are of estuarine origin, the greater part of the coal is interstratified with limestones containing the remains of marine animals. Most of the fossils, indeed, of those coal-tracts, such as Nautilus, Productus, and Spirifer, with Crinoidea and Crustacea, unquestionably inhabited the sea.

Even in the lowest or estuarine zone of Scotland, large Sauroid Fishes, Megalichthys Hibberti, Agass., and Holoptychius Hibberti, Agass., were associated with the Shark-like Fishes Gyracanthus formosus, G. tuberculatus, Ctenacanthus, &c. In the great central limestones remains of these Placoid Fishes are also abundant. They are chiefly Cestracionts (or rather Cochliodonts, Owen, Geol. Mag., Feb. 1867). Their teeth (Cladodus, Diplodus, &c.), or the hard

* See an excellent general sketch of the chief Carboniferous deposits of Europe and America, with illustrations of the prevailing plants, in Lyell's Manual of Geology, 1851, 24th and 25th Chapters; and 5th edit., 1855. See also Ansted's 'Ancient World,' and Prof. Morris's valuable paper on Coals and Coal-plants in the Proc. Geol. Assoc. vol. i. pp. 170 & 289.

† Having under consideration the enormous area occupied by the Carboniferous strata of North America, the late Professor H. D. Rogers endeavoured to reconcile the conflicting hypotheses respecting the origin of coal. (See Transactions American Assoc. Adv. of Science, 1842, p. 433.) He ingeniously applies the opinions of his brother, W. B. Rogers, and himself, respecting the influence of great paroxysmal earthquakes which affected the earth's crust in ancient periods, and suggests how the alternations of terrestrial and oceanic remains to which attention has been called in this Chapter, and particularly at pp. 296 *et seq.*, can best be explained.

‡ See 'Russia in Europe and the Ural Mountains,' vol i. p. 89 *et seq.*, pl. 1, and large woodcut showing the vertical succession, p. 111.

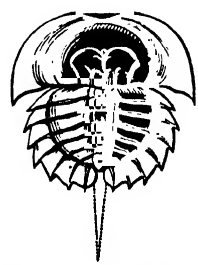
§ This view of the two modes of formation of coal, which I have long advocated (see 'Russia in Europe,' *loc. cit.*, and 'Siluria,' p. 280), has been adopted and well illustrated by Mr. D. Page in his 'Advanced Text-book,' p. 154; and it is fully treated in the last edition of Mantell's 'Wonders of Geology' (1858). The inquirer who wishes to study the British fossil plants of this period must consult the 'Fossil Flora' of Lindley and Hutton. The same subject is still more developed by M. Adolphe Brongniart, who has given his views in an admirable sketch of the successive floras imbedded in the crust of the earth. The publications on the fossil Plants of Germany, by Corda, Göppert, Unger, and Geinitz, are productions of high merit. On comparing these works with those on the coal-plants of America, described by Lesquereux, Rogers, and others, we find that, like the associated marine animals, the same species inhabited very distant regions, or had a wide range through many latitudes.

bony palates of other genera—Psammodus, Cochliodus, Helodus, &c., together with the fin-defences above mentioned, are the only parts preserved; but these are sufficient to show that they were very numerous as individuals, and consisted of many genera. These must be studied in the great work of Agassiz, or in the subsequent publications of Sir Philip Egerton and other authors *.

In the coal-field of Kilkenny in Ireland a very important discovery has recently been made of several remains of Reptiles, which will be treated ofwhen the organic remains are described (p. 303).

FOSSILS (77).

A LIMULOID CRUSTACEAN OF THE CARBONIFEROUS PERIOD.



Prestwichia rotundata (Limulus, Prestwich). From the Coal-measures of Coalbrook Dale.

It is in the purely marine or central limestones of the Carboniferous epoch that the geologist takes his final leave of Trilobites. Abounding in the Silurian era, these Crustaceans have dwindled to a comparatively small number in the Devonian, whilst in the Lower Carboniferous, the three genera Phillipsia, Griffithides, and Brachymetopus mark the last appearance of any individuals of this family in the ascending scale of primeval deposits. On the other hand, it is among the upper coal strata, where Trilobites become extinct, that we see the first representatives of the Limulus, the type of a suborder of Crustaceans which has existed from that early period to the present day with but comparatively little change in its structure.

One example of these old Limuloid animals is here given; it is a rarer species than Belinurus trilobitoides (Limulus, Buckland †). Prestwichia anthrax (Limulus, Prestwich) is another rare form also from Coalbrook Dale ‡. Not only are there Crustacea of the tribe to which the King-crab belongs in the coal, but other Crustacea of a higher order; for, both in the South Staffordshire coal-field and in those of Glasgow and Manchester, a peculiar form, probably of the Schizopod group, occurs, which Professor Huxley has described under the name of Pygocephalus Cooperi; and to this group, too, most probably belongs the carapace from Coalbrook Dale figured by Sir Charles Lyell, in his Manual of Geol. 5th edit. p. 388, which was first referred to Apus by Milne-Edwards, and more lately regarded as a Crustacean of the Shrimp family by Mr. Salter. Nor must we omit to mention the large Eurypteri found in the Glasgow coal-field, and first described by Hibbert in the Trans. Roy. Soc. Edinb. vol. xiii. These, with some others, an Amphipod? (Gampsonyx or Uronectes fimbriatus, Jordan) from Germany, and numerous Bivalved Entomostraca, chiefly of small size, show the fauna of the coal to have been rich in Crustacean forms. Still higher Articulata, the Scorpion and Spider, also appear for the first time in the Coal-measures (Bohemia and Silesia).

Here also we last meet with any large Orthocerata. Those predaceous mollusks of the ancient seas have now begun to diminish rapidly, and with them most of the genera of Cephalopods which have a simple form of air-chamber, their office being taken, in the Triassic and later Secondary strata, by other groups of Ce-

* See 'Palichthyologic Notes,' by Sir Philip de M. Grey Egerton, Bart., M.P., in several volumes of the Quart. Journ. Geol. Soc. See also the Decades belonging to the Memoirs of the Geological Survey of England, in which that distinguished naturalist has published admirable descriptions of many fossil Fishes. The collections of Ichthyolites made by Sir P. Egerton and his associate, the Earl of Enniskillen, are, it is believed, unrivalled.

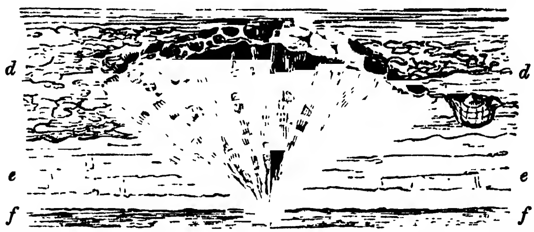
† See the Bridgewater Treatise, pl. 46″. fig. 3,—that very remarkable work of my eminent friend the late Dean of Westminster.

‡ Trans. Geol. Soc. vol. v. pl. 41 f. 1, 4.

phalopoda, such as Ceratites, Ammonites, &c., in which the air-chambers are minutely foliated at their edges.

The true characters of the very numerous genera and species of fossils which occur in this group must be studied in other works; but in support of the opinion that the Corals of the lower division often lived on the spot where they are found, a woodcut is here given of a gigantic specimen of Lithostrotion floriforme *, Sil. Syst., the lower parts of which are rooted in the shale, *f*, whilst the

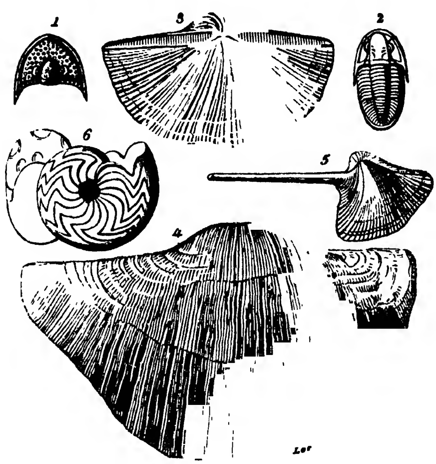
FOSSILS (78). CORAL OF THE MOUNTAIN-LIMESTONE.



Lithostrotion floriforme, Fleming, in its natural position in the rock.

upper portion is imbedded in a limestone, *e*, with a mass of red concretions, *d, d.* This Coral, when in its native bed, appeared, therefore, to be precisely in its original position, and conveyed to me the impression that it had remained

FOSSILS (79). SOME FOSSILS OF THE CARBONIFEROUS LIMESTONE.



1. Brachymetopus Ouralicus, de Vern. 2. Phillipsia pustulata, Schloth. (Ph. gemmulifera, Phill.). 3. Spirifer striatus (?), Martin. 4. Productus giganteus, Sow. 5. Pleurorhynchus aliformis, Sow. 6. Goniatites crenistria, Phillips.

undisturbed beneath the sea, whilst fine red sand at one time, and mud with calcareous matter at another, were deposited around it. The small figure to the

* My friend Mr. Lonsdale, who, as before stated, described all the Corals in the 'Silurian System,' does not admit the generic word *Lonsdalia*, as applied to this form by M. Milne-Edwards, he, Mr. Lonsdale, having first defined and limited the genus Lithostrotion. See 'Russia and the Ural Mountains,' vol. i. p. 602, 1845; and Annals of Nat. Hist., Nov. 1851.

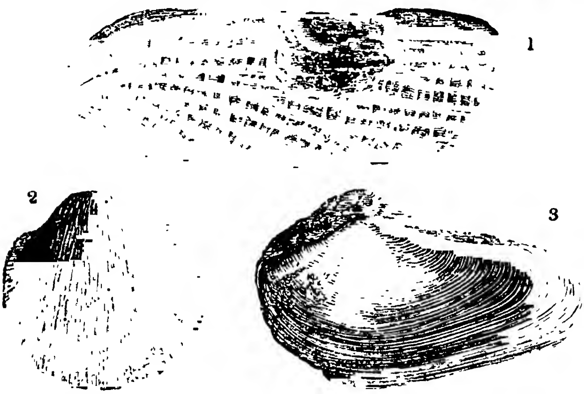
right in the woodcut represents the large shell, Productus hemisphæricus, which in nature is four inches broad, and shows by comparison the very great size of the Coral, which has a width of two feet five inches *.

Of all its fossils, however, the large Producti are the most characteristic of the great limestone group, the same species being found in this rock through many degrees of latitude in Europe, Asia, and America, and even in India and Australia.

Besides these numerous evidences of the presence of the sea, Unio-like shells (Anthracosiæ), probably of estuarine habitats, every now and then occur in thick layers as we ascend in the series, and are among the most characteristic of the upper portions of the formation.

An estuarine intermixture is observable in coal-bearing strata of parts of Shropshire, Staffordshire, Lancashire, and elsewhere. It is well seen in the district

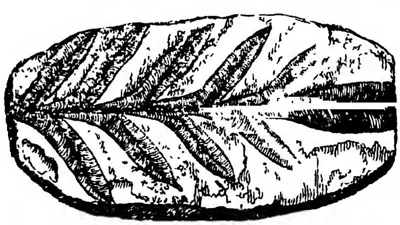
FOSSILS (80). INSECT AND SHELLS OF THE COAL-MEASURES.



1. Wing of Corydalis? Brongniarti, Mantell.
2. Productus scabriculus, Sowerby.
3. Anthracosia acuta, Sow., sp. (Formerly supposed to be allied to Unio. Silur. Syst. p. 105.)

of Coalbrook Dale, where remains of Insects (allied to the Corydalis of America) are found associated with Marine and Estuarine Shells and Land Plants. The figures in Foss. 80 represent this case of intermixture as formerly pointed

FOSSILS (81). FERN FROM THE COAL OF COALBROOK DALE.



Pecopteris lonchitidis, Sternberg. (From Sil. Syst. p. 105.)

out by myself. A fuller account, however, is given of it by Mr. Prestwich, in his elaborate memoir on the strata and fossils of that district †.

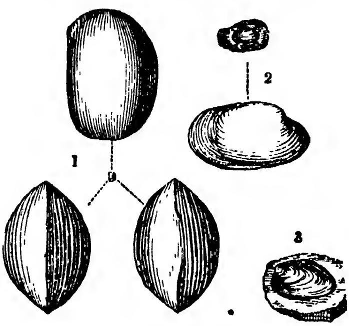
* See Silurian System, p. 107. This Coral is from Lilleshall, Shropshire, where the limestone rises out from beneath the coal.

† Trans. Geol. Soc. Lond., 2nd ser., vol. v. p. 413. One of the Plants, Pecopteris lonchitidis, which is given in the woodcut, Foss. 81, is associated in these tracts with forty or fifty species of terrestrial Plants belonging to Calamitaceæ, Polypodiaceæ, and Lycopodiaceæ. Of these, Stigmaria ficoides (root of Sigillaria), Neuropteris cordata, Odontopteris obtusa, and the Pecopteris here figured are perhaps the most common.

Other probable examples of such associations, indicating the contiguity of land on which Plants grew, and from which they were transported during long periods into estuaries, are seen near Shrewsbury and other localities, among some of the younger coal strata, which at Manchester are seen to be of very great thickness. In the environs of Shrewsbury, small Cyclas-like Shells and valves of a dwarf variety of the little Crustacean Leperditia * are commingled in the same limestone with a minute Shell, originally termed Microconchus carbonarius, but now referred by naturalists to the marine and estuary genus Spirorbis †. The above-mentioned shells, indeed, may also be of marine origin.

The following figures (Foss. 82, 83), formerly published in the 'Silurian System,' explain more particularly the contents of this peculiar limestone of the coal strata.

FOSSILS (82). UPPERMOST LIMESTONE OF THE COAL-MEASURES. (From Sil. Syst. p. 84.)



1. Leperditia inflata (Cypris, Sil. Syst.); magnified 12 times. 2. Anthracosia? (Cyclas or Edmondia?, Sil. Syst.); natural size, and magnified 4 times; from near Shrewsbury. 3. Anthracomya (Modiola, Sil. Syst.), from Ardwick, Manchester, in a band of limestone of the same age. (From Sil. Syst. p. 84.)

In all such cases, and still more where the coal is intercalated, as before said, among purely marine animal remains, we must believe that the vegetables from which it was formed were carried down into seas or estuaries fed by freshwater affluents, of which condition the little fossil Estheriæ (E. striata, E. tenella, E. punctatella) are perhaps the best evidences ‡.

With the proofs in our possession of the large quantities of terrestrial vegetables which occur in the Carboniferous era now under consideration, accompanied as they are in numerous cases by river and lake Shells, and in other instances by Insects and Arachnida, it might be expected that Reptiles would also be procured from them; and such has proved to be the case. The first discovery of this nature was made in the coal-field of Saarbrück in Rhenish Bavaria (a coal-field also rich in Insects), wherein two species of Archegosaurus, Goldfuss, have been found,—a Reptile which Hermann von Meyer supposes to be a connecting link between Batrachians and Lizards.

Since then the footsteps of a large Reptile allied to the Cheirotherium have been observed in the Carboniferous strata of Pennsylvania; and Professor M'Coy detected in the Museum of Lord Enniskillen the remains of a small Rep-

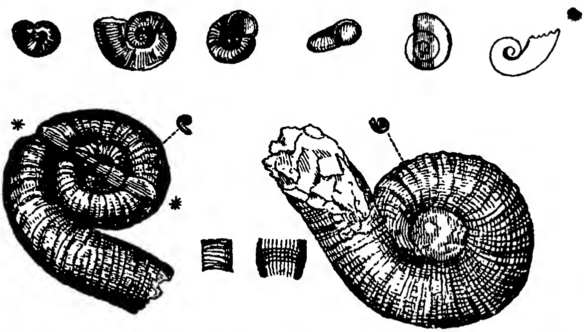
* This little marine animal was formerly known as Cypris inflata. See a critical examination of the characters of these and other minute Bivalve Entomostraca, by Prof. T. Rupert Jones and Mr. J. W. Kirkby, in the Ann. Nat. Hist. 3rd ser. vol. xviii. p. 36 &c.

† Some of the coal sandstones in the environs of Manchester exhibit on their surfaces the clearest indications of having been shore-deposits, certain tracks having been marked on them by animals which must have crawled at ebb-tides. Mr. Binney states also that the shells of Spirorbis occur throughout the whole of the thick series of the Lancashire coal-field, and thus indicate the long-continued action of marine conditions. See a valuable paper 'On some Trails and Holes in the Carboniferous Strata, with Remarks on Microconchus carbonarius,' by Mr. E. W. Binney, Transactions of the Literary and Philosophical Society of Manchester, vol. x., 1851–52.

‡ See Rupert Jones's Monograph on the fossil Estheriæ, Pal. Soc. 1866; also Quart. Journ. Geol. Soc. vol. xix. pp. 141 &c.; and Trans. Geol. Soc. Glasgow, vol. ii. p. 71.

tile from one of the Scotch coal-fields, which Owen has described under the name of Parabatrachus Colei. Owen has also described the Anthrakerpeton crassosteum from the Coal-shale of Glamorganshire; and Huxley has described several reptiles from the Coal of Scotland and Ireland (see p. 303). The Labyrinthodont Baphetes planiceps (Owen) was found in a coal-seam at Pictou, Nova Scotia. Sir C. Lyell has published the very interesting account of a discovery made by Principal Dawson and himself, in the coal-field of South

FOSSILS (83). UPPERMOST LIMESTONE OF THE COAL-MEASURES. (From Sil. Syst. p. 84.)



Microconchus (or Spirorbis) carbonarius, Sil. Syst. The real size is given in the minutest of these figures, whilst the upper figures are somewhat magnified, and the lower very greatly so. * *. The mark of attachment to some small cylindrical body.

Joggins, in Nova Scotia†, of a Reptile called Dendrerpeton Acadianum, which Owen and Wyman consider to belong to the Perennibranchiate Batrachians. With this Reptile were associated remains of others, many Land Plants, and several shells of an air-breathing Mollusk—the first true Land Shell found in strata of such high antiquity‡. These discoveries afford us proofs of associations of organic remains which we might, indeed, have anticipated.

Principal Dawson has since discovered, in the Coal-formation of Nova Scotia, five new species of Reptiles, namely:—Hylonomus Lyelli, Dawson; H. aciedentatus, Dawson; H. Wymani, Dawson; Dendrerpeton Oweni, Dawson; and Hylerpeton Dawsoni, Owen §. Vertebræ referred to a much larger Reptile, Eosaurus Acadianus, have also been found and described by Mr. O. C. Marsh; and Mr. Brown, of Sydney, has discovered a slab with footprints referable to still another species, Sauropus Sydnensis, Dawson. The genera Hylonomus and Eosaurus are supposed to represent higher types of reptilian life than that of the Labyrinthodont Batrachians. Another new air-breather, a Centipede or Myriapod, allied to Iulus, also discovered by Dr. Dawson in the Coal-formation of Nova Scotia, is Xylobius Sigillariæ; and similar fossils have lately been found in Britain ‖.

In our own islands, also, footmarks of Sauroid animals have been detected in the coal-field south of Edinburgh ¶; and the impressions of the feet of another reptilian

† Quart. Journ. Geol. Soc. vol. ix. p. 55.

‡ Ibid. vol. ix. p. 58.

§ Quart. Journ. Geol. Soc. vol. xvi. p. 268, vol. xviii. p. 5, and vol. xix. p. 52; Canadian Naturalist and Geologist, vol. viii.; Dawson, 'Air-breathers of the Coal-period.'

‖ In January 1867, Mr. Henry Woodward communicated to the Glasgow Geological Society an account of the discovery of Xylobius (probably X. Sigillariæ), from the clay-ironstone of the coal-measures of Kilmaurs, near Glasgow; and in the same month Mr. E. W. Binney recorded the discovery of another specimen in the Manchester coal-field (Proc. Manch. Lit. & Nat. Hist. Soc.). A reptilian jaw-bone, like that of Dendrerpeton, has been recognized in Mr. Atthey's collection of fossils from the Newcastle coal-field, by Prof. R. Jones: Geol. Mag. vol. i. p. 130.

¶ See H. Miller's 'Testimony of the Rocks,' p. 78.

animal have been found in the coal-field of the Forest of Dean *. According to Professor Owen, these last-mentioned footmarks might have been produced by the wriggling movements of a Salamandroid quadruped. They very much resemble some of the impressions called Steropezoum, Anomœpus, and Triænopus by Hitchcock; but "of these," Owen adds, "no more definite idea is entertained than a vague one of their having been produced by a kind of great Newt-like Reptile."

A great accession to the fossil fauna of the Carboniferous period has recently been made in Ireland. Professor Huxley, who in the year 1862 described a remarkable Labyrinthodont from the Lanarkshire coal-field of Scotland †, under the name of Anthracosaurus Russelli, has recently described no less than eight distinct genera of Labyrinthodont Amphibia from the coal-field of Kilkenny, with indications of others. These are associated with the fossil Fishes Megalichthys, Gyracanthus, and a new genus of large Ganoids, Campylopleuron. Of these eight genera of Labyrinthodonts, three, viz. Keraterpeton, Urocordylus, and Lepterpeton, were salamandroid animals, provided with long tails and well-developed fore and hind limbs; in Urocordylus the superior and inferior spines of the caudal vertebræ are so prolonged as to leave no doubt that the tail was a powerful instrument of propulsion. Of another and probably similar form, Erpetocephalus, only the skull has been discovered. In two other genera, Ophiderpeton and Dolichosoma, the greatly elongated and eel-like body appears to have been devoid of limbs. Ophiderpeton attained a length of more than three feet. Of the seventh genus only the hinder part of the body has yet been found; it is a much larger animal, which probably attained a length of not less than six or seven feet, and resembles, if it be not identical with, the Anthracosaurus of the Glasgow coal-field. The eighth, Ichthyerpeton, has a fish-like body, with very short and thick hind limbs. The skeletons of these animals are all well ossified. Several of the genera certainly, and all probably, were provided with a ventral armour, resembling that of Archegosaurus and Pholidogaster.

Some of Professor Huxley's conclusions are most important, since they tell us that one Irish coal-pit has yielded in a few months more genera of vertebrate animals higher than Fishes than are known from all the vast American coal-fields, and nearly as many as have been found in all Europe. This discovery shows also that the Labyrinthodont type of Reptiles (as Huxley says) "was abundantly represented in the Carboniferous epoch by animals with well-ossified vertebræ, with no trace of persistent branchiæ, and to all appearance just as highly organized as their congeners in the Trias."

The Coal-field of Edinburghshire also has yielded two Labyrinthodont Reptiles—Loxomma Allmani, Huxley, and Pholidogaster pisciformis, Huxley.

In the earliest wide and general diffusion of a copious and peculiar vegetation previously spoken of, we recognize the prevalence of the equable temperature and similar conditions over various latitudes which must, in my opinion, have also existed, to a great extent, in the preceding periods.

The specific identity, also, of many of the Brachiopods of the Lower Carboniferous rocks situated at enormous distances in latitude from one another (*e. g.* from the Arctic circle to the south of the Equator) is an additional and striking proof of the general uniformity of temperature and marine conditions during this epoch. The discovery also by Livingstone, on the banks of the Zambesi, in South Africa, of coal strata the fossil Plants

* This specimen is in the Museum of the Geological Society, and was sent to me by the Rev. Charles H. Bromby.

† Quart. Journ. Geol. Soc. vol. xix. p. 56.

of which left no doubt of their ancient date, and the still more recent announcement of extensive coal-fields in Brazil, in nearly the same southern latitude, are striking proofs of the widespread uniformity of these conditions when the Carboniferous flora prevailed. Professor Agassiz, who examined them, declared the Brazilian fossils to belong to the old Carboniferous age; and on inspecting the fossil plants from Brazil recently submitted to me by Lord Stanley, Her Majesty's Secretary for Foreign Affairs, I came to the same conclusion; whilst Dr. Percy, by analysis of various samples of these coals, found their chemical composition and structure to be in harmony with the decision of the palæontologist*.

In respect to the origin of coal, I still adhere to the idea which I broached many years ago, and illustrated by a map, that coal may in some instances have been the result of the transport of great matted masses of trees and vegetables into marine estuaries (Sil. Syst. p. 152). The original observation, however, of Logan, that the roots of many of the fossil trees are seen to be implanted in the under-clays of the respective coal-beds, proves the existence, over very large areas, of coal-growths *in situ*, or, in other words, that such beds of coal were simply subsided jungles. It has indeed now become the general opinion of geologists that most of the coal has resulted from such littoral growths, in maritime swamps or lagoons, of various trees and vegetables suited to these conditions, and that the occurrence of marine spoils among and over the beds of coal has resulted from subsidences of that vegetation beneath the sea. It is certainly more likely that there should have been subsidences, with periodical pauses, in coal strata 12,000 feet thick, like those in South Wales, than that there should have been repeated oscillations of the land—descending to receive marine productions, and raised again to sustain the growth of terrestrial plants. If the plants grew like mangroves in the West Indies, and if the water was very shallow, running into muddy lagoons, and full of sand-bars near low swampy shores (a condition quite in accordance with what is represented in the vignette, p. 286), we should not need to invoke such repeated changes of level, but simply appeal to subsidence with occasional pauses. In confirmation of this view we have the fact that, with the exception of the so-called 'Unio-bands,' there is very little evidence of freshwater conditions at all; while the abundance of Spirorbis carbonarius, Leperditia, and Beyrichia, occasional bands of Goniatites and Aviculæ even in the true coal-shales, and the frequent occurrence of marine Shells and shark-like Fish point to a condition of things much more like that of the mangrove-swamps above alluded to. It is further remarkable that in existing lagoons is found a species of Unio nearer in character (according to the late Professor E. Forbes) to the so-called Unios of the coal than any true freshwater form.

In illustrating these views, the geographical conditions under which coal has probably been accumulated have been clearly and ably set forth by Mr.

* The little Palæozoic Beyrichia has also been found in the shales of the Brazilian coal-measures by Prof. Rupert Jones: Geol. Mag. vol. i. p. 132.

Godwin-Austen, in a memoir in which he delineated the north-western coal-area of Europe (Quart. Journ. Geol. Soc. vol. xii. pp. 38 &c., pl. 1).

The later researches of Mr. H. C. Sorby, directed from another point of view, indicated the trend and character of the marine currents of the coal-bearing sea-margin. This author, to whom we are indebted for so many good observations in physical geology, has arrived, by independent researches, at the conclusion that the seas of the Coal-period (in the North of England) were enclosed and shallow, with no very fixed or determinate lines of drift or current. In some valuable notes with which he favoured me *, he shows that during the deposition of the older slate-rocks of Westmoreland and the Lake District, or the Lower Silurian time, the currents came chiefly from the east, and that in the Upper Silurian period they proceeded from the N.N.W. These facts, when further developed, must throw great light on the physical geography of early times. He further indicates that during the period of the Carboniferous Limestone and Millstone-grit the sea was open to the west.

These regular currents, however, as he shows, cease to be conspicuous when we rise into the Coal-measures in the same districts, the general current having then become almost extinct, and a confused set of tidal and wind drifts having supervened, which indicate a very considerable alteration in the outlines of the region. These changes point, first, to a diminution of the current-flow in the period of the Millstone-grit, then to a far more limited extension of the water during the Coal-period, ending in a fresh set of currents during the Permian era, among elongated shoals.

With such data before us, we are, perhaps, warranted in believing that a theory of the formation of coal which should embrace as its chief element a widely extended series of shallow and partially enclosed seas, fringed with swampy forests of water-loving plants, subject to frequent submersion, accords well with observed phenomena.

In geological researches we frequently meet with results that cannot be fully explained by one *modus operandi* only; for nature has evidently worked out phenomena apparently similar through distinct processes; and of this no better indication can be given than that coal may well have been formed out of vegetable matter by the above-mentioned different processes †.

Bituminous Shale and Petroleum.—In closing this Chapter on the old Carboniferous deposits, I may be excused for saying a few words upon the recent discovery of the outflow of vast quantities of petroleum or stone-oil in North America, and of the distillation of the same substance from the bituminous shale of British Coal-fields, particularly those of Scotland. If all the stone-oil which exudes from the crust of the earth in various

* See also his papers on this subject in the Edinb. New Phil. Journ. vol. iii. p. 112, iv. p. 317, v. p. 275, vii. p 226.

† Various interesting conclusions arrived at by Principal Dawson, from his long-continued researches on the nature and character of Coal and its mode of accumulation, will be found in his memoirs, 'On the Structures of Coal,' Quart. Journ. Geol. Soc. vol. xvi. pp. 268 &c.; 'Air-breathers of the Coal-Period,' Montreal, 1863, p. 18, &c.

countries, or issues when the covering strata are pierced, proceeded from the ancient Carboniferous deposits which we have been considering, the explanation of the phenomenon would be comparatively easy; for, whether the immense masses of matted vegetables of that period were solidified into coal and shale, or converted into the liquid substitute petroleum, the true source of that substance would be evident. In Shropshire, however, petroleum is seen to exude from fissures in old Cambrian rocks (see p. 27), in Caithness from ichthyolitic flagstones of the Old Red Sandstone (p. 258), and in North America it is said to issue chiefly from the Devonian formation, in a tract where comparatively few fossil vegetables or animals are discovered in the rocks; and in these cases the explanation is exceedingly difficult. The old belief of chemists was that bitumen can be derived only from vegetable or animal matter; and as neither of these in any appreciable quantity has been detected in the Cambrian rocks, we must in such case suppose that, though they have disappeared in the stony matrix, vast quantities of sea-weeds prevailed when these strata were in the condition of marine mud, and that the decomposition of these sea-weeds has produced the petroleum. But this view is not altogether satisfactory.

Another theory is, that in some cases the presence of stone-oil is due to the former existence of Carboniferous strata over the oil-yielding area (as in parts of North America, for instance), and that the coal-fields were once extended over the ancient Cambrian rocks above mentioned, north and south of Shrewsbury, and, before and during their denudation, the bituminous contents of the coal-strata sank into the subjacent rocks through cracks and fissures, and occupied cavities within them. It is highly improbable, however, that this theory should be applicable to such cases as those where petroleum exudes from very ancient rocks, which rise into mountainous masses like the Longmynd, and which were unquestionably raised into dry lands before the coal-formations were accumulated. If, then, we retain the old chemical doctrine of the derivation of petroleum, we must revert to the theory that, as in all the marine deposits, however ancient, in which any traces of animal life exist there must also have been Algæ, there may have been a sufficiency of them to account for the small amount of petroleum found in such rocks.

In the younger deposits, as they begin to show an increase in vegetable and animal life, carbonaceous and bituminous ingredients abound more and more in the strata. That some of the shales of different epochs have been rendered bituminous chiefly through the abundance of animals entombed in them, may be surmised even in regard to the anthracite of the graptolitic schists of the South of Scotland, and to that which has been detected in the Silurian rocks of Cavan in Ireland (see p. 183).

The presence of stone-oil in the Devonian rocks was probably due both to the conversion of masses of Sea-weed and to that of the numerous

Fishes of the period. Thus, in the Caithness Flags of that epoch, we know perfectly that the beds have been rendered bituminous by their numerous Ichthyolites (see p. 258, *ante*).

Ascending from the Old or great Coal-period to the youngest Tertiary formations, we are seldom at a loss to account for the presence of bitumen and petroleum; for in most of these deposits both animal and vegetable substances abound. Thirty-eight years have elapsed since I described the process of distilling oil by the application of heat to rocks of the age of the Lias in the Tyrolese Alps, which had been rendered highly bituminous by the immense quantity of fossil Fishes entombed in them *. Indeed as we ascend through the series of Secondary deposits, highly bituminous shales are sometimes found, as in the well-known case of the Kimmeridge Clay. Again, the large pitch-lakes of Trinidad and Venezuela are known to exude from Tertiary lignites, such as also yield bitumen in Persia and other places, especially in the great tract on the south-west shores of the Caspian, extending inland from Baku.

Although I cannot yet accept as widely applicable the theory of my distinguished friend, M. Abich, that, in other cases, petroleum is a compound primitive body engendered in the interior of the globe (see note, p. 27, *ante*), the recent researches of that eminent French chemist Berthelot have gone far to sustain that view, and to show that this substance may have a purely mineral as well as an animal and vegetable origin. Adopting the hypothesis suggested by Daubrée, that the terrestrial mass contains free alkaline metals in its interior (apparently a part of the volcanic theory of Davy, as supported by Daubeny), M. Berthelot, believing that carbonic acid does infiltrate through various parts of the crust, simply asks us to admit that this acid may descend to the heated alkaline metals; and then the result must be the formation of acetalides. After various chemical reactions which he explains, these substances would, under given conditions, constitute petroleum. M. Berthelot sums up in these emphatic words:—"We can thus conceive the production, by a purely mineral method, of all the natural hydrocarbons,—the intervention of heat, water, and alkaline metals. Lastly, the tendency of the carbides to unite together so as to form matters more condensed suffices to account for the formation of these curious compounds. This formation can also be effected in a continuous manner, since the reactions which produce it are incessantly renewed" †.

The consideration, however, of the origin of petroleum or stone-oil will be resumed in the 18th Chapter, when the able views of Dr. Sterry Hunt on this subject will be explained. It will then appear, by reference to the Reports on the Geology of Canada, that in North America petroleum is indigenous, on a very large scale, to the Lower Silurian, Lower Devonian, and Lower Carboniferous limestones.

* Annals Philos. 1828.

† Annales de Chimie, Dec. 1866, vol. ix. p. 482.

CHAPTER XIII.

PERMIAN ROCKS.

CHANGES OF THE FORMER SURFACE.—ORIGIN OF THE TERM 'PERMIAN' AS APPLIED TO THE HIGHEST GROUP OF PALÆOZOIC DEPOSITS.—THE PERMIAN ROCKS OF RUSSIA, GERMANY, AND BRITAIN.—THE ORGANIC REMAINS OF THE GROUP.

IN the two previous Chapters, slight allusions only have been made to igneous or volcanic materials ejected and spread out on the sea-bottom contemporaneously with the ordinary sedimentary deposits; for during the Devonian and Carboniferous eras such eruptions were by no means so abundant in the British area as when the Lower Silurian rocks were accumulated. (See pp. 76 &c.)

The great Upper Coal-fields considered in the previous Chapter were probably, in regions like Britain and America, evolved under conditions which geologists would consider comparatively quiescent. This is supposed to have been particularly the case with those coal-beds which were formed either by continuous depressions of low lands beneath the waters or by alternations of subaqueous and terrestrial surfaces. The close, however, of that period was specially marked by ruptures of the crust of the earth, which, from the physical evidences placed before us, must have extended over very distant regions. Whatever may have been the previous changes, it was then that the coal-strata and their antecedent formations were very generally broken up, by upheavals, into separate troughs and basins, distorted by numberless powerful dislocations. The order of ancient sedimentary succession was thus very widely, though not universally, interrupted; and all the strata previously spoken of were so disturbed as to produce a prevalent break or discordance between the Carboniferous deposits and those which succeeded to them.

This disturbance, however, was not general, since there are exceptional tracts in which the Carboniferous and overlying Permian deposits are in apparently conformable relation to each other.

The general effect of the great disseverment alluded to, in determining a former outline of the earth, is obvious; for, whilst the Silurian, Devonian, and Carboniferous rocks were at that period so heaved up as to constitute portions of mountain-chains, the strata which we are now considering have been for the most part spread out in lesser elevations, constituting countries with a lower level. Yet, notwithstanding these physical changes, the animals and plants of the Permian era, though chiefly of new species, are generically connected with those of the preceding or Carboni-

ferous epoch; whilst they are almost wholly dissimilar to those of the next succeeding period, the Trias.

The strata which were accumulated immediately after the great deposits of Coal have been termed in England Lower New Red Sandstone, Marl-slate, Magnesian Limestone, &c. Similar rocks have long been known in Germany under the names of Roth-todt-liegende, Kupfer-Schiefer, Zechstein, &c. Having become satisfied that all these strata, so different in mineral character, constituted one natural geological group only, clearly distinguished from the Carboniferous series beneath, and, on account of its organic contents, must be entirely separated from all formations above, in 1841* I proposed to my associates de Verneuil and von Keyserling, when we were in Russia, that these rocks should receive the name of 'Permian,' a term taken from an extensive region which composed the ancient kingdom of Permia, of which the extensive Government of Perm forms a part. To that vast tract the illustrious Humboldt particularly called our attention when M. de Verneuil and myself were about to revisit Russia; and in it we found all the characteristic features of this independent assemblage developed on a very grand scale.

After two explorations of Russia, I reexamined when alone (1844) those portions of Germany where the Zechstein and its associated strata, underlying as well as overlying, are best displayed; and, by placing these in parallel with the Russian and English rocks, my views were confirmed; and thus all the deposits above mentioned were included under the term 'Permian.' The value of this euphonial name, for a series of strata composing one natural group, soon became so obvious that, proposed in 1841, it has since been adopted by nearly all geologists of different nations.

In Germany, where the Roth-todt-liegende, Kupfer-Schiefer, and Zechstein had long had their headquarters, and where their characters had been described by numerous geologists, from the days of Werner and Schlotheim to those of the great geologist Leopold von Buch, whose loss we deplore, these rocks have been recognized in the works of Naumann of Leipsic, of Geinitz and Gutbier of Dresden, and of Göppert of Breslau, as the 'Permische System' †.

In France, the late M. Alcide d'Orbigny, in his systematic work on Palæontology ‡, and other authors, have given currency to a name which would, indeed, have had little or no value without the close palæontological comparisons of my colleagues de Verneuil and von Keyserling, as worked out with me in the easternmost regions of Russia-in-Europe.

* The term was first proposed in a letter addressed by me at Moscow to the venerable and accomplished Russian palæontologist Dr. Fischer, October 1841. Bronn und Leonhard's Jahrbuch, 1841, and Phil. Mag. vol. xix. p. 417.

† See Geinitz and Gutbier, 'Permische System in Sachsen,' 1848. Since the last edition of this work was issued, my friend Professor Geinitz deserted the name Permian which he had adopted, and, following M. Desor, applied the name of *Dyas* to this system. I have elsewhere resisted the introduction of a new name founded upon a local binary division which, though good in Saxony, is inapplicable to many other countries, in several of which the separation is tripartite. In North America (see Chap. xviii.) it is indeed a *Monas*. I am happy to observe that the mass of geologists prefer the simpler geographical name 'Permian,' which, like 'Silurian,' involves no theory.

‡ See Cours élémentaire de Pal. et Géol. Strat., par Alcide d'Orbigny, vol. ii. p. 370.

In the north of England, the different deposits which are now united in a group were admirably described by Sedgwick *, who clearly showed their relations to the German rocks of like age. Professor Phillips †, indeed, first suggested, that, on account of its fossils, the 'Magnesian Limestone' of England should be classed with the Palæozoic rocks. Subsequently the organic remains of the Magnesian Limestone have been illustrated by King ‡, Howse §, Kirkby ||, and other authors, under the term 'Permian'; and the word has been used for some time in the construction of the Geological Survey Map; also Binney ¶, Ormerod **, Harkness ††, and other geologists have all employed it in their writings.

As many persons may not have access to the large volumes on the geology of Russia, in which a full description is given of the leading characters of the group in that Empire, and as I wish to put the reader into possession of the reasons for the adoption of the name 'Permian,' a few passages from the writings of my colleagues and self are here reproduced. By the first of these extracts it will be perceived that, in describing the whole structure of Russia, we began, as on the present occasion, with the lowest rocks in which any traces of life could be detected.

"Having worked our way upwards through Silurian, Devonian, and Carboniferous rocks, we have now to describe the next succeeding natural group. Spread out over a larger surface than any others in Russia, the rocks in question, with certain overlying red deposits, which we cannot separate from them, occupy the greater part of the Governments of Perm, Orenburg, Kazan, Nijni Novgorod, Yaroslavl, Kostroma, Viatka, and Vologda, a region more than twice the size of the whole kingdom of France!" ‡‡

After showing to what an extent opinions varied respecting the age of these Russian deposits, most authors referring them to the New Red Sandstone or Trias, others to the Carboniferous era, it was next observed §§:—

"Such was the state of the question when we entered upon the survey of Russia. To arrive, therefore, at a sound conclusion respecting the age of these rocks, it became essential to traverse, as far as possible, the countries over which they extended, and compare the phenomena which had led to such contradictory opinions. The result has been, that, though these deposits are of very varied mineral aspect, and consist of grits, sandstones, marls, conglomerates, and limestone, sometimes enclosing great masses of gypsum and rock-salt, and are also much impregnated with copper, and occasionally with sulphur, *yet the whole group is characterized by one type only of animal and vegetable life.*

"Convincing ourselves, in the field, that these strata were connected by their organic remains with the Carboniferous rocks on the one hand, and were independent of the Trias on the other, we ventured to designate them by a geographical term derived from the ancient kingdom of Perm, within and around whose precincts the necessary evidences had been obtained.

* Trans. Geol. Soc. n. s., vol. ii. pp. 37 *et seq.*

† Treatise on Geology, p. 189.

‡ Monograph, Palæont. Soc. 1856; Ann. Nat. Hist. 2 ser. vol. xvii.; and Journal Geol. Soc. Dublin, vol. vii.

§ Ann. Nat. Hist. 2 ser. vol. xix. pp. 33 &c.

|| Quart. Journ. Geol. Soc.; Annals Nat. Hist.; Trans. Tyneside Nat. Club.

¶ Mem. Lit. & Phil. Soc. Manchester, vols. xii. and xiv.; Quart. Journ. Geol. Soc. vol. xii. p. 138, and vol. xviii. p. 439.

** Journ. Geol. Soc. vol. vii. p. 268.

†† Quart. Journ. Geol. Soc. vol. xii. p. 267, &c.

‡‡ Russia-in-Europe, vol. i. p. 137.

§§ Ibid. p. 138.

"With the highest respect for the labours of German geologists upon the Zechstein, and for the researches of those authors who have placed the Magnesian Limestone of England on the same parallel, we are convinced that neither in Germany nor in Great Britain do the same accumulative proofs exist to establish the independence of a geological system. If mineral characters be appealed to, no German writer will contend that the thin course of 'Kupfer-Schiefer' is of like importance with the numerous strata which in Russia constitute many bands of various structure, rendering, in fact, the Zechstein itself a mere subordinate member of a vast cupriferous series. Subordinate, however, as it is in some tracts of Russia, the Zechstein is so magnificently displayed in others, in masses of both limestone and gypsum, that it more than rivals the finest sections of that deposit, whether to the south of the Harz or in Thuringia. We object, however, to a lithological name hitherto reserved for one portion only of a complicated series; and as the Germans have never proposed a single term for the whole group which is based upon the Roth-todt-liegende, and surmounted by the Trias, we have done so, simply because we first found in Russia the requisite union of proofs."

Occupying the enormous area before mentioned, the Permian deposits of Russia are flanked and underlain on nearly all sides by different members of the Carboniferous rocks, containing comparatively little coal. These Permian strata of Russia seldom offer a mineral succession similar to that of formations of the same age in Western Europe. In different tracts of the vast region explored, they exhibit, as explained in the preceding quotation, many variations in their mineral and organic contents, as well as in the relative position of the component masses. In some places, as on the River Kama, near its junction with the Volga, cupriferous red grits with Plants underlie the chief limestone, and are succeeded by marls; but along the eastern limits of the group, where it is flanked by the Ural Mountains, gypseous limestones form the base, followed upwards by the red copper-grits, sands, marls, limestones, and pebble-beds, which extend on all sides around the city of Perm. On the whole, indeed, whether we appealed to the sections on the banks of the great Dwina, above Archangel, to the western flank of the Ural Mountains, or to the banks of the Lower Volga, near Kazan, localities at vast distances from each other, we found that the limestones, of which there are several bands, often interstratified with much gypsum, prevailed towards the base of the Permian deposits of Russia.

In parts of the region salt-springs occur. Some of these may possibly rise from solid bodies of salt in older Palæozoic rocks, since the mineral is known to occur in the Devonian rocks of Livonia; but in the steppes south of Orenburg, masses of rock-salt rise to the surface, and are certainly subordinate to red Permian deposits *. These salt-beds range up to the base of the older Palæozoic and crystalline masses of the South Ural Mountains to the east of Orenburg, the strata of Permian age being visible only in the low wooded slopes at the foot of the rocky chain, as represented in the vignette at page 312.

Along certain portions of the west flank of the same chain, the Permian strata occur in almost apparent conformity to the Carboniferous rocks. There they have manifestly undergone a movement impressed on them by great forces directed from north to south, or parallel to the Ural Mountains, all the strata, whether Carboniferous or Permian, having been raised up, and thrown off sharply to the west †. From the Gurmaya Hills on the east to the Hill of Girialskaya

* Russia-in-Europe, vol. i. p. 184.
† See section, 'Russia-in-Europe,' vol. i. p. 146, and 'Siluria,' 1st ed. p. 296.

on the west, the following succession is exhibited in ascending order in proceeding from the Silurian and Devonian rocks of the Ural chain:—Carboniferous

THE GURMAYA HILLS OF THE SOUTH URAL MOUNTAINS.
As seen from the Steppes of Orenburg. (From 'Russia-in-Europe,' vol. i. p. 450.)

Limestone, with the usual large Producti and other fossils, passing upwards into Carboniferous Flags with slight traces only of coal. These rocks are followed by the Permian group, consisting of:—1. Sandstones and grits, limestones in various courses, with fossils of the Zechstein of Germany, associated with marls, gypsum, &c.; 2. Red sands, with copper-ores and many Plants; 3. Conglomerate and sandstone, with fossil Plants and Reptiles.

At the Imperial Baths of Sergiefsk, and on the banks of the River Sok, a tributary of the Lower Volga, magnesian limestone and marl contain gypsum, copper-ore, native sulphur, with sulphureous and asphaltic springs in the middle masses, whilst other marlstones and white limestones constitute the summit. A considerable volume of gaseous, sulphureous water, which forms a large pool, issues from these rocks. (See diagram, 'Russia-in-Europe,' vol. i. p. 158.)

Near Kazan, about 150 miles to the north of Sergiefsk, huge masses of gypsum * (*a*), rising high above the level of the River Volga, are surmounted by limestone cliffs with Zechstein fossils (*b*), and the latter by red, green, and white marls (*c*), as here represented.

W. PERMIAN DEPOSITS NEAR KAZAN. (From 'Russia-in-Europe,' p. 162.) E.

a. Thick deposit of gypsum. *b.* Limestone with well-known Zechstein fossils. *c.* Red and green shelly marls, also with Zechstein types.

* Cliffs of white gypsum, subordinate to the Permian rocks, are still more conspicuous on the banks of the Dwina south of Archangel, where they form white cliffs for many miles, and again near Pinega, where with my companions I examined them in the year 1840.

On the contrary, in the central tracts between the Ural Mountains and the Volga (as on the Dioma and Kidash, tributaries of the River Kama) the limestone, which in some tracts assumes a definite horizon and is underlain by coarse grits, is repeated at various levels in a succession of beds, interlaminated with sandstones, as well as yellow, white, and greenish marls, occasionally containing Plants, also small seams of impure coal,—the whole being surmounted by red grits and conglomerates, with copper-ore.

The calcareous and gypseous deposits which interlace this series are throughout characterized by a similar group of fossils, and even by some of the same species as those of the Zechstein of Germany and the Magnesian Limestone of England; whilst the beds of copper-grit, with the greatest part of the red conglomerates, which in the vast undisturbed region of Permia are uppermost, contain bones of a genus of Reptiles which in Germany occurs in the copper-slate beneath that limestone. Plants, also, which are generically allied to the old Carboniferous flora are of frequent occurrence in the Governments of Perm, Orenburg, and Kazan, where they often lie in red sands and marls above all the limestones. Indeed several of these vegetables are identical with species described by Colonel Gutbier from the argillaceous beds of Zwickau in Saxony, belonging to the Rothliegende beneath the Zechstein; and Göppert has since demonstrated the generality of this arrangement.

The exploration of this diversified Permian group of Russia, therefore, taught geologists not to dwell on the local mineral distinctions of Central or Western Europe, but to look to the wide spread of certain fossil remains, which, in vastly distant countries, occupy the same general horizon, though in different subdivisions of a group which clearly lies between the Carboniferous rocks beneath and all those overlying strata which are called Secondary or Mesozoic.

The survey further proved, by the extension of some of these fossils upwards into red and green marls and sands far above the chief bands of limestone with well-known Zechstein fossils, that the Zechstein could no longer be properly considered, as in Germany, the summit of this natural group. Let us now, therefore, consider the natural features and characters of the group in that country.

Permian Rocks of Germany.—Before the publication of the work entitled 'Russia and the Ural Mountains,' above referred to, and three years after the word 'Permian' had been proposed, I reexamined those tracts of Germany where rocks of this age are best developed and had long been known through the writings of native geologists. Having since explored these lands upon three different occasions, during the first two of which I was accompanied by Professor Morris, and in the last by Professor Rupert Jones, a condensed view, with some additional illustrations, of the development of this natural group in Germany is offered.

In the early days of our science, when Werner and his cotemporaries clearly distinguished the different strata now united as the Permian group, it was natural that geologists should adopt the names applied to these rocks by the miners of Saxony. The extraction of copper from a widely persistent but thin course of dark-coloured cupriferous shale, necessarily led the native workmen to assign certain names to the strata above and below the money-making band. Hence, the overlying red variegated sandstones being generally named 'Bunter Sandstein,' or variegated sandstone, the limestone beneath this, and immediately above the copper-schist, was termed 'Zechstein' *; the whitish and

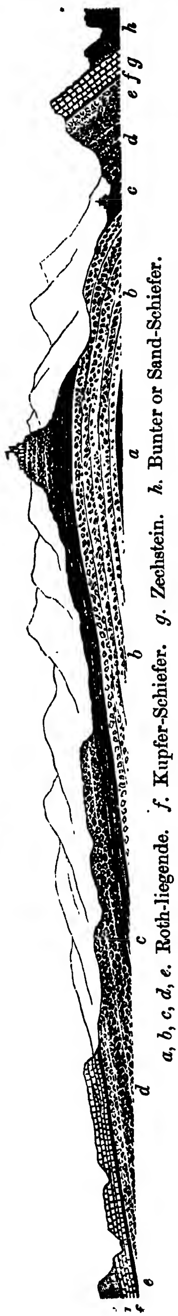
* In a letter to myself, Leopold von Buch suggested that the word Zechstein was probably derived from the Italian Zecchino, or Sequin, formerly a well-known coin in Germany, because this calcareous rock was the cover which, being pierced, led to the bed of ore from which the miner derived his profit.

grey pebbly beds subjacent to this metalliferous layer, and in which a little copper-ore is also occasionally diffused, were designated 'Weiss-liegende;' and the great underlying mass of red conglomerates and sandstones, in which no trace of ore was detectable, received the expressive name of 'Roth-todt-liegende,' or the 'Red dead underlier.' These names having remained attached to such rocks, it is far from my wish to disturb any of them. On the contrary, in proposing the term 'Permian' I wished simply to show that they constitute one natural group terminating the Palæozoic series, as seen in the region of Permia. This group, distinct from the Coal-formation beneath, has for its base the Roth-todt-liegende, and for its summit the lowest and thinnest member only of the great deposit of red and variegated sandstone, known in Germany as the Bunter Sandstein. This view, which I applied to the German succession after my last exploration of Russia in 1844, was the natural result of the similarity of the fauna and flora of this age in both countries.

As there is no portion of Northern and Central Germany in which the Permian group is more obviously separated from all underlying and overlying strata than in the tracts which flank the Thüringerwald, let us first consider its relations in those interesting districts. Ranging from S.E. to N.W., the chain of the Thüringerwald is mainly composed, in the former direction, of those Silurian, Devonian, and Lower Carboniferous rocks which were formerly merged under the term 'Grauwacké,' and the relations of which will be explained in the subsequent Chapter on Germany. Towards its north-western termination the nucleus of the range consists of crystalline schists pierced by granitic rocks and greenstone, as well as by porphyries, which throw off on both the south-western and north-eastern faces strata composing the Permian group. In proceeding from the S.E. to the N.W., or along the axis of the chain, the observer finds that he is travelling along a ridge chiefly occupied by porphyries, both black and red (the latter much predominating), and constituting the highest watershed of the wild woodlands, known as the Rennsteig. On either side of this central axis there are valleys, both longitudinal and transverse, forming deep indentations in the chain itself, in some of which there are exceptional outcrops of grey and dark-coloured schistose beds, occasionally containing a few fossil Plants, and in rare localities some beds of coal. These strata, differing considerably in mineral character from the Lower Carboniferous strata which have been raised up with the Devonian and Silurian rocks of the Southern Thüringerwald, manifestly belong to the so-called Upper Coal of Germany. Such coal is most developed at the southern end of the Thüringerwald, where several beds of it have been reached by shafts which pass through vast thicknesses of overlying Roth-liegende. Towards the N.W., these deposits, detected at but few spots, have been found to contain coal only in the valleys west of Ilmenau, where, in the vicinity of certain eruptive rocks, the coal-beds are brought near to the surface.

The object in here alluding to these Carboniferous strata, whether productive of fuel or not, is simply to point out that wherever they can be observed they are here, as in other parts of Germany, unconformably and transgressively overlain by the Roth-liegende. Whilst the former, judging from their fine lamination and imbedded fossil Plants, resulted from tranquil deposition under water, the latter was formed during a period of great disturbance of the surface, accompanied by the extrusion of much igneous matter, and the powerful aqueous translation of many broken materials of preexisting rocks. It is by the unmistakeable signs of such causation that the basement strata of the Permian group are so visibly characterized, and that they differ so essentially from those which preceded them.

In truth, various rocks of igneous origin have penetrated the Thüringerwald from a very early period; but it is only on ascending to the Roth-liegende that we are surrounded with cotemporaneous porphyry; so that, as well laid down on Credner's map, the northern part of the chain is seen to be, to a great extent, occupied by red porphyries, which rise to the highest central summits, such as the Inselsberg and Schnee-Kopf, the latter 3300 feet above the sea. It was therefore in this, the earlier part of the Permian era, that those grand protrusions or eruptions took place, from S.E. to N.W., which obscured the ancient physical direction of the slaty rocks that trend from N.E. to S.W., and determined the notable fact that the axis or watershed of the ridge ranges from S.E. to N.W., or at right angles to the strike of the old slaty ridges.



SECTION ACROSS THE NORTH END OF THE THÜRINGERWALD, NEAR EISENACH, SHOWING THE PERMIAN ROCKS.

a, b, c, d, e. Roth-liegende. *f.* Kupfer-Schiefer. *g.* Zechstein. *h.* Bunter or Sand-Schiefer.

The porphyries which ushered in a new series of deposits are immediately flanked on either side of the Thüringerwald by the Permian group, which is interposed between the older rocks and the tranquilly deposited Trias. Now, at the north end of the Thüringerwald, where all such older rocks subside, as at and near the town of Eisenach, the core of the chain is composed exclusively of a splendid development of Roth-liegende, succeeded on either side by all the other members of the Permian group, the whole being symmetrically united. Here, in the deep valleys excavated in the Roth-liegende, the tourist meets with picturesque cliffs amidst luxuriant foliage; and here it is that the geologist is specially invited, with Credner's map and Senft's descriptive work in his hand, to study the characters of the lowest member of Permian deposits, which, in this neighbourhood, is expanded to the vast dimensions of at least 4000 feet. This fact has been ascertained by boring through the lowest visible portions of this great accumulation in search of coal, to the depth of 2600 feet in nearly horizontal strata, and by adding to the subjacent red sandstone, shale, and pebble-beds the thickness of the overlying deposits which are exposed in this hilly tract. In the lowest strata bored through were found fragments of silicified Plants (stems of Araucarites, &c.), similar to those which will presently be spoken of as occurring in the escarpments of the Kyfhäuser, to the south of the Harz.

The reader will therefore understand that, thick as the Roth-liegende appears to be in the accompanying woodcut, which I prepared in 1857 after reexa-

mining the tract in company with my able instructor Professor Senft of Eisenach, and Professor Rupert Jones, it is the upper portion only of that deposit which is exposed. All the ascending order from it to the superjacent Permian rocks has now, by the cutting of the Frankfort Railroad, been as clearly laid open to the W.S.W. as it was previously on the eastern or opposite side of Eisenach. The reader who inspects this section will, therefore, have a good idea of the development of the Permian rocks of Northern Germany, with the exception of the lowest beds of the Roth-liegende.

At the north-eastern extremity of the Thüringerwald, the mass of red rock *a* in the section is seen to be covered by about 1400 feet of strata of red breccias, conglomerates, sandstones, and shale (*b*, *c*, *d*), terminating upwards in the light-coloured or whitish conglomerate (*e*) which supports the Kupfer-Schiefer (*f*) and Zechstein (*g*), surmounted by the Bunter Schiefer (*h*).

The bands of the conglomeratic series, well exposed on the sides of the steep hills on either flank of the valley of Eisenach, and under the lofty hill on which stands the old Castle of Wartburg, celebrated as the residence of Luther, have been named by Professor Senft, in ascending order, thus:—

1. Quartz-conglomerate (*b*). This is truly a breccia composed of angular fragments, chiefly of quartz, in a red matrix, but with some fragments of mica-schist, slaty rocks, old porphyries, &c. This rock, though extensively denuded in the valley of Eisenach, rises to the west of the town into peaked and turreted masses having a thickness of 600 feet. It is well to remark here that this and the other so-called conglomerates of this age in many parts of Germany are essentially angular breccias, which could not have been formed by the rolling action of waves on a shore, but must have been tumultuously and suddenly heaped together.

2. Dark red shale and sandstone (*c*), 250 feet. These beds, on the contrary, mark a period of quiescence, when the finely triturated sand and mud were accumulated.

3. Granitic conglomerate (*d*), also a breccia; chiefly distinguished by containing fragments of a granite now unknown in the Thüringerwald, but resembling a rock still visible in the Harz. This breccia, with interlaminated bands of deep-red sandy shale, supports the Castle of Wartburg *. Folding over to the west, this last-mentioned rock has been tunnelled through in making the railroad to Frankfort, and is ascertained to have a thickness of about 500 feet.

Now, whether we follow these rocks to the west or to the east, we find that the uppermost portion of the granitic breccia or conglomerate, *d*, as indicated in the section, graduates upwards into, and is succeeded by, another conglomerate, *e*, of a light-grey colour, and therefore called locally the 'Grau-liegende' †, by Senft. This is the 'Weiss-liegende' of most German authors, and lies immediately beneath the Kupfer-Schiefer. Mineralogically, it is perfectly united with the subjacent Roth-liegende and with the overlying Copper-slate, *f*, by the diffusion of slightly cupriferous green earth through all the junction-beds. Again, in ascending still higher, an equally clear transition into the overlying limestone is seen by the conglomerate becoming somewhat calcareous and cupriferous; whilst in other parts of Germany, as near Gera, fossils even of the Zechstein have been found in this conglomerate subjacent to the Kupfer-Schiefer. Then follows the thin black course of the Kupfer-Schiefer, *f*, with its

* This is the castle in which the great Protestant reformer, Luther, was secluded by the Elector of Saxony.

† The employment of this term, 'Grau-liegende,' is not fortunate; for Geinitz applies it, as we shall presently see, to the lowest member of the deposit near Dresden. 'Weiss-liegende' is the usual term.

numerous and well-known fossil Fishes, which is succeeded by the thick-bedded Zechstein, *g*, and its overlying dolomitic members and thin layers of fetid limestone, the 'Stinkstein' of the Germans. In other sections on the sides of the Thüringerwald gypsum occurs (and occasionally in large masses) in this upper limb of the limestone, as at Rheinhardts Brunnen on the east, and again near Liebenstein on the west; but on either side of Eisenach the dolomite is simply succeeded by thin-bedded upper courses of fetid limestone or Stinkstein.

Here, however, as indeed everywhere in this region of Germany, the highest calcareous layers of the Zechstein are conformably overlain by red shale and sandstone, somewhat calcareous in some of its beds, and passing upwards into flaggy red sandstone (*h*, in the foregoing section). This last-mentioned rock was formerly classed by native geologists with the overlying Bunter Sandstein; as, however, it forms the natural cap of the Zechstein, I united it with that rock—the more so as throughout large regions of Russia it is in marls, sandstones, and conglomerates lying above the Zechstein with fossils that Plants and Proterosauri are found which are identical with species from the Roth-liegende of Germany beneath that limestone.

In addition to the proofs drawn from the environs of Eisenach *, many other sections precisely similar might be cited from either flank of the Thüringerwald, the details of which are given elsewhere; for, whether we refer to the eastern side of the northern portion of the chain at Schmerbach, Kabarz, and Seebach, or to the western side at Kupfersuhl, Glücksbrunn, and Marksuhl, the subdivisions of the Permian group are seen to be naturally united †.

A similar order is observable in the undulating region which extends northwestwards from Reichelsdorf to the banks of the Fulda. Whilst the Kupfer-Schiefer of the tract around Reichelsdorf has afforded numerous fossil Fishes and other remains, it is on the right bank of the Fulda, betwren Rotheburg and Altmorschen, on the north side of the railroad leading to Cassel, that the clearest evidences are afforded of that transition from the Zechstein upwards into overlying sandstones on which I lay so much stress. There the Zechstein is observed to form the central mass of the red hills, having in its higher part large masses of gypsum, more or less amorphous, which are capped by thin layers of fetid limestone. The upper bands of this limestone, parting with their calcareous matter, gradually pass up into red schistose and flagstone layers and red and green marls, the whole covered by whitish-coloured pebbly sandstones. All this succession is often clearly exposed in one and the same hill, the strata being slightly inclined to the north.

A like succession is further traceable along the eastern face of the older schistose rocks (chiefly Devonian), which range from Marsberg and Arolsen by Sachsenhausen, and are even traceable at Marburg. Reappearing in the broad Permian tracts of the Wetterau, the same relations are prolonged to the environs of Hanau, east of Frankfort on the Maine ‡.

* The explorer who has only a few hours at his disposal should walk up the high ground called Göppels Hüppe, S.E. of Eisenach, and there see how conformably the Zechstein is capped by the red 'Sand-Schiefer' (see the section at p. 315).

† For detailed illustrations of this order of the Permian rocks on the flanks of the Thüringerwald, see the transverse sections, pl. 3, which accompany M. Credner's Geological Map; also the memoir by myself and Professor Morris, Quart. Journ. Geol. Soc. vol. xi. p. 424, with sections.

‡ The divisions of Roth-liegende, Zechstein, and Lower Bunter Sandstein were so correctly laid down by M. Ludwig in the Geological Map of the country to the N.E. of Frankfort, that the geologist has but to unite these three under one name, and he has at once the Permian group. The finest collection of the fossils from the Zechstein of the Wetterau is in the possession of M. Roessler of Hanau. Numerous Permian species of Mollusks, Corals, Entomostraca, &c. which are common to Britain on the west and Russia on the east, are found at the localities of Selters, Bleichenbach, Hajgründen, Büdingen, Rückingen, &c.

In all these countries, and throughout the region between the Thüringerwald and the Harz, there is, I maintain, no difficulty whatever in separating the red rocks which form the natural cover of the Zechstein from the real formation of Bunter Sandstein, which is naturally connected with the Muschelkalk, and forms the true base of the Trias. On this point it may further be observed that in no part of Germany has there been detected in the sandstone forming the cap of the Zechstein a fossil which can be referred to a Mesozoic age; whilst the only Plant found in such red rock is the Calamites arenaceus, Jäger, which is manifestly a Palæozoic form.

Reverting to the great inferior member of the Permian group, attention should be specially paid to its extraordinary variation in thickness—a characteristic feature, indeed, of all conglomerates. Thus, whilst, as above cited, it has a thickness of 4000 feet at Eisenach, yet, near Schmerbach and Seebach, a few miles only west of that place, where porphyries rise up behind it, no more than 100 or 200 feet of this deposit are exposed; and yet we there see quite as clear and conformable a transition from the red rock beneath into the 'Weiss-liegende' above it, and thence into the Kupfer-Schiefer and the overlying Zechstein, as in the large diagram at p. 315.

Permian Rocks surrounding the Chain of the Harz.—The older sedimentary rocks constituting the nucleus of the Harz, and the chief eruptive rocks of that remarkable region, will be described in a subsequent chapter. The Permian deposits which form a girdle around that mountainous mass, which trends from W.N.W. to E.S.E., or nearly at right angles to the original direction of the older and elevated rocks, are quite analogous in their general relations to those of the Thüringerwald and the broad tracts to the west of it; but there are local features peculiar to the Harz which demand notice. As around the Thüringerwald, we equally well see the same ascending order of the three chief subdivisions, all symmetrically united in one physical group which is separated from the Upper Carboniferous rocks beneath, and from everything Triassic above it; in like manner, also, the conglomerates of the Roth-liegende are found to be local accumulations only, extremely thick in some places, and very thin (or even dying out) in others.

Referring to another work * for such variations of detail exhibited by the Roth-liegende and overlying deposits as are seen in the environs of Mansfeld and Eisleben, there are still, however, two features in the Permian group as exhibited in the region around the Harz which deserve notice. These are, that the lower members of the Roth-liegende, which are not exposed at Eisenach (p. 315), are much developed, and, next, that the upper member of the Zechstein is more largely composed of masses of gypsum, often amorphous, and attaining enormous dimensions †.

Although there are many places along the southern and eastern flanks of the Harz where the upper member of the Roth-liegende is well exhibited, particularly in its relations to the overlying Zechstein, and of which proofs have already been given, the tract where the inferior member is, as far as I know, most fully displayed is on the northern escarpment of the bold Permian outlier the Kyfhäuser—so called from the ruins of an imperial residence, of that name, which stands on one of the north-eastern summits of this hilly and insulated mass.

* See memoir by myself and Prof. Morris, Quart. Journ. Geol. Soc. vol. xi. p. 409.

† The Permian rocks of Mansfeld, Eisleben, and the Kyfhäuser Hills, especially in relation to their copper, silver, and gypsum, have been described in detail by Mr. W. P. Jervis, F.G.S., in the 'Journal of the Society of Arts' (1861), vol. ix. pp. 592, 603, 616, &c.

On proceeding from Stolberg and its old rocks on the south flank of the Harz, and reaching the town of Kelbra in the rich valley termed the Goldene Aue, the surface of the red-coloured arable fields is seen to be studded with fragments, often 2 or 3 feet long by 1 or 2 feet in diameter, of silicified stems of trees, which for the most part belong to the Plants termed Araucarites and Psaronites, the latter being unknown in any other deposit save the Roth-liegende of the Permian group.

Standing on this red plain, the spectator has in face of him, to the south, a noble escarpment rising to upwards of a thousand feet high, the whole of which, ranging westwards from the ancient tower of the Kyfhauser by the Rotheberg, is composed of various strata of the Roth-liegende, whether of pebbly beds, sands, or shales, piled symmetrically on each other. In parts, as near the well-known and picturesque Hermitage on the Rotheberg, so much frequented by German summer tourists, the deposits have been broken through by eruptive rocks, chiefly syenitic greenstone; but a little to the west of this disturbance all the strata are admirably exposed in the sides of the great highroad leading to Frankenhausen, which, by a series of traverses, mounts up to the summit of the hills. Now, whether, in making that ascent, we examine the base, as composed of finely laminated, earthy, deep-red sandstone, or the middle, of harder and more thickly bedded sandstones, or approach the summit, where light-coloured pebbly beds, used as millstones, are largely quarried (the latter being covered by other red marls and sandstones), we find throughout numerous fossil trees, regularly imbedded and lying either in horizontal positions or slightly oblique to the strata *.

To the west and south-west, these noble masses of red conglomerate and sandstone, followed by other red strata, are seen to be succeeded by the Zechstein, with huge associated bodies of gypsum, which in their turn are surmounted in the same hills by other red rocks.

Here again, therefore, as everywhere in Northern Germany, the tripartite division is apparent, and the Zechstein (in this tract usually with masses of gypsum) is seen to be simply the central body of the great red Permian group.

There are, however, many spots along the south flank of the Harz, and also to the south of the Kyfhäuser promontory, where the gypsum is swollen out to masses of enormous dimensions, and is devoid of a regular capping of red sand, or indeed of any superjacent stratified deposit. In these cases it would seem that a former agency acting from beneath, along a great line of fissure, has greatly affected the rock, and changed the carbonates of lime into sulphates; for there are some places where the bedding and colour of the layers are still evident, and others, again, where the whole have been converted into amorphous and unstratified masses of huge dimensions. Not only do these masses of gypsum form lofty escarpments, usually blanched by atmospheric action, but at Frankenhausen †, where extensive salt-works have long been carried on, the borings were made through 1173 feet to reach the rock-salt. Now, in all this thickness, with the exception of the uppermost 93 feet, which consisted of red sand, apparently the detritus of the overlying red strata of the country, the whole subterranean mass was found to be gypseous, with occasional intercalations of limestone and argillaceous way-boards, as if to show that the sub-

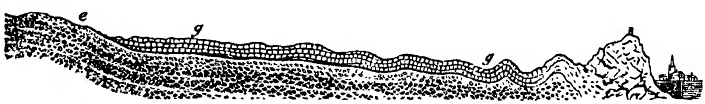
* So numerous are these fossil trees, that ten of the largest are arranged around a central pyramid of other and thinner stems on the summit of the high road leading from Kelbra to Frankenhausen. The large silicified stems on the exterior, some of them 3 to 4 feet in diameter, form seats. One tree, lying *in situ*, and crossing the strata obliquely, measured 42 feet in length, with a diameter of 18 inches.

† See Map of the Kyfhäuser and Frankenhausen, Leonhard und Bronn's Neues Jahrb. 1847, pl. 13.

stances had once been regularly stratified. This phenomenon, in a tract the northern part of which is characterized by stratified rocks of the same age and of no great thickness, affords a strong argument in favour of metamorphic action having proceeded from great depths, and of its having acted in this expansive manner along a line of fissure.

That this huge and irregular mass of gypsum at Frankenhausen is the result of a great change is proved by proceeding from the north southwards, along the highroad which traverses the Kyfhäuser promontory. There the lower flag-like calcareous layers of the Zechstein are seen to slope away regularly, at a small angle from the red sandstones on which they repose. Next, after some contortions, the whole rocky precipitous cliff, from the summits of which the watch-towers of the ancient town of Frankenhausen frown over the southern plains of red land, is seen to consist of gypsum, in most of which there is no regularity of stratification. The bore-hole at the base of this cliff was also chiefly made in gypsum; but M. von Dechen informs me that there were occasional interpolations of limestone and argillaceous schist with various sandstones †; so that, whilst the German geologists consider this gypseous mass to be subordinate to the Upper Zechstein only, I would suggest that the fact of the intermixture of such mineral substances looks very like the result of a great disturbance, accompanied by a considerable change of character in the rock. My own views are expressed in this generalized woodcut:—

RELATIONS OF GYPSUM TO THE ZECHSTEIN AT AND NEAR FRANKENHAUSEN.



d. Lower Roth-liegende. *e.* Upper Roth-liegende. *g.* Zechstein. *g**. Altered Zechstein and gypsum.

The phenomenon of the vast expansion of gypsum occurs at various other places on the southern flank of the Harz, and is strikingly demonstrated at Artern, ten miles east of Frankenhausen, and probably on the same line of metamorphism. There, according to von Dechen, the strata, consisting of—1st, overlying red sandstone; 2ndly, gypsum; 3rdly, Zechstein in the form of stinkstein; 4thly, gypsum—were penetrated both by shaft and borings to the depth of 1017 feet before the rock-salt was reached ‡.

In this way we obtain evidence that in Northern Germany, just as in the south-eastern Steppes of the Kirghis to the south of Orenburg § in Russia, the rock-salt and gypsum are fairly subordinate to the Permian group, both these mineral masses having apparently resulted from metamorphic action.

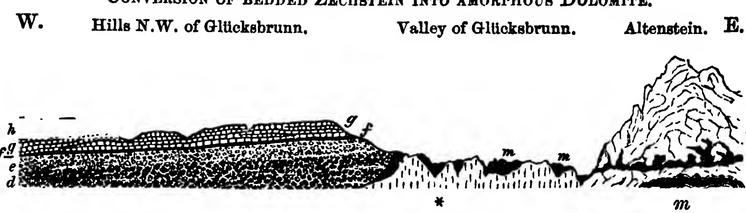
† I am indebted to my friend Geheimrath H. von Dechen, the celebrated geologist (to whose great map I shall hereafter have occasion to refer), for all the information I possess respecting the borings at Frankenhausen. He further states that the gypsum was traversed by numerous cracks, the deepest of which was seen at 743 feet below the surface, such cracks being filled with sand and pebbles.

‡ After a visit to Salzungen in the company of the late Duke Bernhard of Saxe Weimar, I infer that the saline waters of that place, which lie to the west of the Thüringerwald, and which German geologists have placed in the Bunter Sandstein, really rise, like the salines of Frankenhausen, Artern, and many other places, from rock-salt subordinate to the Permian group. The shafts at Salzungen having passed through the red sandstone, borings were made to a depth of 500 feet, in which gypsum was traversed, as well as dark argillaceous strata.

§ 'Russia and the Ural Mountains,' vol. i. p. 184.

The geologist who follows the Zechstein along various tracts is constantly, indeed, induced to account in a similar manner for a sudden expansion of that bedded deposit into amorphous dolomite; for, although there are numerous tracts where the upper portion of the formation is a regularly bedded magnesian limestone resembling that of Britain, yet as we often see the rock at the distance of a mile from where it is a flat-bedded limestone of small dimensions suddenly swell out into a precipitous, amorphous mass, characterized by caverns and irregular joints, it seems impossible to doubt that this change has also been caused by a powerful metamorphosis. This rapid change can be observed by any one who, frequenting the baths of Liebenstein on the west flank of the Thüringerwald, shall first examine the stratified Permian hills to the west of Glücksbrunn, with their strata of Weiss-liegende and Kupfer-Schiefer surmounted by Zechstein and red flaggy sandstone (Lower Bunter), and then cross from the escarpment over several protrusions of porphyry in the valley to the east, which have much altered the strata in contact, until he is stopped by the precipitous face of the towering masses of dolomite which suddenly rise up and constitute picturesque eminences 200 feet above the low tract, as in this woodcut.

CONVERSION OF BEDDED ZECHSTEIN INTO AMORPHOUS DOLOMITE.



d. Roth-liegende (not seen in this part of the tract). *e.* Weiss-liegende with some copper-ore. *f.* Kupfer-Schiefer, rich in copper-ore and fossil Fishes. *g.* Zechstein, with fossils. *h.* Red sandstone (roof of the Zechstein). *g**. Altered Zechstein (Dolomite). *. Eruptive rocks. *m.* Micaceous schist and altered rocks.

The identity of the amorphous subcrystalline dolomite of the cliff with the stratified limestone of the adjacent lower country is here demonstrated by the clearest evidence; for the same species of shells which exist in the flat-bedded strata, *g*, of the low arable hills on the east are here detected in the unbedded wild cliffs of dolomite with their deep fissures and long caverns, *g**.

In thus briefly alluding to the striking features of amorphous gypsum and dolomite which reoccur at intervals in many parts of the range of these limestones of the Permian group, it is also to be noted that along these lines of metamorphism the same rocks often contain rich masses of spathose and hematitic iron-ores. This is specially observable on the western flank of the Thüringerwald, to the east and south of Liebenstein, where the Zechstein has been intruded upon by porphyritic and granitic rocks.

In advancing from the environs of Saalfeld, where the Zechstein and Weissliegende (the latter becoming red in parts) rest upon the edges of the Upper Devonian and older Carboniferous rocks, we meet with numerous knolls of gypsum, both stratified and amorphous, with much iron-ore, both of which have been described by Richter †; whilst at Essig and Pössneck the calcareous matter again rises up in apparently unbedded dolomitic bosses, which on disintegration have afforded numerous characteristic fossils ‡.

† Einladungsprogramm der Real-Schule, &c., Saalfeld, p. 21.
‡ The Altenburg of Pössneck has afforded to the researches of the Rev. Mr. Schubert a fine collection of fossils.

Persistent in its character of contraction and great local expansion, the Roth-liegende, which has thinned out at Saalfeld, resumes its importance at Gera, near to which place it is to be partially seen, underlying and fairly passing into the Weiss-liegende; whilst to the north of that city, the lower red deposit, rising out from beneath all the Zechstein series, swells out to a vast thickness, and again occupies a broad tract extending far into Saxony on the north and east. The memoirs of Dr. Liebe, of Gera *, have fully explained the positions of the fossils which occur in such abundance in the environs of Gera, and which can be so well studied in the fine collection of M. Dinger of that town †.

The material point which I seek to establish is, that there, and on the right bank of the Elster, the geologist sees a section which leaves no doubt of the propriety of binding together the different members of the Permian group in the manner indicated.

It is true that on the banks of the Elster, near Gera, the uppermost bed only of the Roth-liegende can be observed; but as this deposit has been pierced to a great depth in fruitless searches for coal on the opposite bank of the stream, no one can doubt that the true Permian foundation-rock is here developed on a great scale. The upper member of the Roth-liegende, which is there visible, presents all the unmistakeable characters of the deposit, being made up of fragments, more or less angular, of quartz, lydian stone, and particles of the older rocks in a deep-red sandy paste, here and there spotted with green. This rock passes gradually, and without the smallest appearance of discordance or separation, into a lighter-coloured conglomerate of about 10 feet in thickness, composed of broken fragments of quartz-rock and greywackè, somewhat ochreous downwards, and becoming white, or light-grey, upwards. The latter rock, containing many of the same fragments as the lower red mass, has in its upper part a calcareous and highly magnesian, instead of a siliceous and argillaceous paste.

Now this whitish conglomerate, which is truly the upper part only of the Roth- and Weiss-liegende, and is conformably overlain by the Kupfer-Schiefer, already contains the following fossils, so typical of the Zechstein in various countries: viz. Productus Cancrini, de Vern., Lingula Credneri, Gein., Strophalosia Leplayi, de Vern., Avicula, Pecten Mackrothi, von Schaur., Terebratula Geinitziana, with the Plants Ulmannia frumentaria and Ul. lycopodioides, Göppert, &c.

In this way the basement conglomerate rocks are linked on by these animal remains, as well as by chemical constitution ‡, to the calcareous central strata. At the same time it is worthy of consideration that the same species of Mollusks were in existence whilst the action which evolved the inferior conglomerates was drawing to a close, and that even subsequent to the appearance of such Mollusks a remarkable change occurred in the sea-bottom, by which the dark-coloured mud, occupied by the remains of peculiar Fishes, and known as the 'Kupfer-Schiefer,' was spread out over a wide region. But the calcareous element recurring, the same Mollusca again flourished, and became still more abundant in the overlying Zechstein.

Difference between the Permian Rocks of Northern and Southern Germany.— Although not yet very exactly defined in geological maps along its southern

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† Dr. Liebe and M. Dinger obligingly accompanied Professor Rupert Jones and myself to the examination of the strata here described; and we were much gratified by the inspection of numerous beautiful fossils in the museum of the last-mentioned gentleman. The collection of the Rev. M. Mackrode is also celebrated.

‡ See Liebe's Notice on the conglomerate Zechstein, Zeitsch. Geol. Gesells. ix. p. 407, which shows an increase of magnesia from the Roth-liegende into the Weiss-liegende, and a greater quantity of it in the pebbly Zechstein than in the overlying Zechstein.

boundary, it may be said that, where the Permian group maintains its full characters, lithological, zoological, and geological, it is a northern deposit. Drifted blocks at Spitzbergen indicating its presence in that region *, we have evidence of its presence in the most northern parts of Eastern Europe, extending even to the White Sea, and ranging southwards throughout Russia, and on the western flanks of the Ural Mountains, to beyond 50° of north latitude, south of Orenburg. In following this parallel to the west, we see that it passes by the northern foot of the Carpathians, and that, trending between the Riesengebirge and the Alps, it traverses the smaller German States and the North of France, to the south of the British Isles, thus leaving to the north all that portion of Europe in which any Permian rocks are known. This geographical feature is dwelt upon because it is essential to observe that, in following the group in Germany from north to south, it is found to part with its principal calcareous centre and fossiliferous member. Thus, to refer once more to the region of the Thüringerwald, rendered so classic by the map of that sound geologist Credner, and illustrated by the able publications of Professor Senft and Baron Schauroth the palæontologist of Coburg, the Permian rocks are seen to part with their calcareous centre as we track them southwards to the district lying between Neustadt and Kronach † in Bavaria. There, huge accumulations of the Roth-liegende, overlapping in highly inclined positions a thin coal-field, are surmounted by a very poor and meagre band of limestone, which further southwards is entirely lost. Again, in approaching the Riesengebirge from the southern part of Prussia on the north, the Zechstein is exhibited for the last time in the tract near Löwenberg, south of Liegnitz. There that rock, resting upon Roth-liegende, and dipping under red sandstone, is, as in other places, a poor and thin deposit when compared with its equivalents on the flanks of the Harz and the Thüringerwald.

As soon as we enter into the Riesengebirge, and thence travel southwards through Bohemia, or even through the southern parts of Saxony, from the environs of Dresden, we nowhere meet with a Zechstein formation like that of Northern Germany. In all this southern region the lower member of the group, preserving locally the ordinary characters of the Roth-liegende of the northern and western tracts, is one great series of sandstones and conglomerates, which, as in the Thüringerwald and the Harz, is ushered in with the evolution of porphyries. In this series are found many fossil Plants, with here and there calcareous courses, often characterized by Ichthyolites of the genera Palæoniscus, Pleuracanthus ‡, Acanthodes, &c.

Whilst the Ichthyolites of these Permian strata south of the Riesengebirge are like those of the Zechstein, except in the case of one of the genera known in the Carboniferous rocks, they differ from the latter, as will presently be shown, in specific characters. In Lower Silesia, and particularly in the district between Friedland on the north and Braunau on the south, the lower members of these red rocks are finely laminated red sandstones, associated with, and in part reposing on, red porphyry; they are covered by other sandstones and conglomerates, and contain within themselves courses of darkish grey or reddish thin-bedded limestone charged with Fishes. In examining a dark band of these limestones at Oel Berg near Braunau §, I could not avoid being struck with the analogy of its position

* See description of the fossils from Spitzbergen by Leopold von Buch, and also by de Koninck and Salter.

† This interesting district was visited by me in 1854, accompanied by Professor Morris, when we were much indebted to M. Büttner of Kronach for conducting us to good sections of the coal-pits, some of which are worked under the Roth-liegende, and others in valleys below the natural escarpments of the red rock.

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Persistent in its character of contraction and great local expansion, the Roth-liegende, which has thinned out at Saalfeld, resumes its importance at Gera, near to which place it is to be partially seen, underlying and fairly passing into the Weiss-liegende; whilst to the north of that city, the lower red deposit, rising out from beneath all the Zechstein series, swells out to a vast thickness, and again occupies a broad tract extending far into Saxony on the north and east. The memoirs of Dr. Liebe, of Gera *, have fully explained the positions of the fossils which occur in such abundance in the environs of Gera, and which can be so well studied in the fine collection of M. Dinger of that town †.

The material point which I seek to establish is, that there, and on the right bank of the Elster, the geologist sees a section which leaves no doubt of the propriety of binding together the different members of the Permian group in the manner indicated.

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and relations to those of the Zechstein of Northern Germany *. The limestone rests upon a black schistose bed, in which copper has been worked; and the whole reposing upon a vast thickness of red sandstone, is immediately and conformably surmounted by reddish, purplish, yellow, and whitish grits, sandstone, and shale. In other parts of Bohemia, Fishes similar to those of Braunau, Rüppersdorf, &c. have been detected in red flagstones. From what we saw, it is probable that there are two or more calcareous beds; for the limestone at Halbstadt, only a few miles to the north of Braunau, is a red and deep-purple rock, wholly unlike that of the Oel Berg, and not containing Fishes.

Again, in the very heart of the conglomerates which, though apparently the oldest beds, constitute alone the whole of the Permian rocks visible to the north-west of Friedland, limestones containing magnesia occur. These brecciated masses and their limestones are well exposed at Traut-Liebersdorf, where the transition from a calcareous conglomerate replete with angular fragments of quartz into a coarse calcareous grit, and from that into a limestone which attains a thickness of 30 feet, is readily seen.

At the Oel Berg near Braunau †, Ichthyolites abound, with many good specimens of which I was supplied through the liberality of M. Benedict Schroll. These fossils have been submitted to the examination of Sir Philip Egerton, who has pronounced them to belong to the genera Palæoniscus, Acanthodes, Xenacanthus (Pleuracanthus), &c.‡. Of these Ichthyolites, the most striking and the largest is a Placoid Fish, with a strong defensive spine inserted immediately behind the head. This is the Xenacanthus (now more properly called Pleuracanthus §) Decheni of Beyrich. It is abundant at Braunau, together with three or four species of Palæoniscus, the chief of which, P. Vratislaviensis, occurs also at Rüppersdorf. Palæoniscus lepidurus and another (like P. Voltzii) occur here or at Ottendorf. There is also a species of Acanthodes, a genus remarkable for its minute square scales. Now no one of these Fishes is of the same species as those of like genera which are found in the subjacent Carboniferous rocks.

The same conclusion has been arrived at by Sir Philip Egerton in the examination of the fossil Fishes of Klein Neundorf, which I brought home in 1857 from the spot. Thus the Acanthodes gracilis from the bituminous schists of that locality, which have been considered to be subordinate to the Roth-liegende, has also been pronounced to be a species distinct from the A. Bronni of the Coal period, a generic resemblance only having led to an erroneous identification.

To the west of this district there exists the remarkable petrified forest of Radowenz and Buchau near Adersbach, described by Professor Göppert, and to which M. Schroll and Dr. Beinert directed my attention: here thousands of tons of silicified stems of trees, chiefly of the genus Araucarites, are found. I much regret not to have visited this sandstone tract, in order to satisfy myself if it really belongs to the Upper Coal, as suggested, or to the Lower Permian. The presence of the Carboniferous plant Araucarites Brandlingii would by no means determine the question; for that plant does occur in true Roth-liegende; and Göppert has decided that at Radowenz it is associated with the new form A. Schrollii. See a translation of Göppert's account of this tree-bearing sandstone, as taken from the Memoirs of the Silesian Society, Ann. & Mag. Nat. Hist. ser. 3. vol. i. p. 236.

* Professor Naumann has shown how such fish-beds occur very low indeed in the Permian rocks at Oschatz in Saxony. (See Quart. Journ. Geol. Soc. Lond. vol. v. p. 2.)

† My really scientific friend in this tract, and who was of great service to me, is the zealous botanist and palæontologist, Dr. Beinert, of Charlottenbrunn, whose museum is most instructive, and whose beautiful Park, which he has opened to the public, is replete with the living and extinct forms of vegetable life, so placed in juxtaposition as to render it well worthy of a visit.

‡ As all the species from the Roth-liegende which have been rigidly compared by competent ichthyologists are found to be distinct from those of the Coal-deposits, I doubt the accuracy of M. Schnur, who has identified the Permian Xenacanthus Decheni with a fossil Fish of the Coal of Saarbruck. (See Zeitschr. Geol. Gesells. vol. viii. p. 542.) A noble specimen of Xenacanthus Decheni (15 inches long) from Rüppersdorf is to be seen in the Museum at Bonn (see Leonh. & Bronn's Neues Jahrbuch, 1849).

§ See note by Sir P. Egerton in the Ann. of Nat. Hist. for Dec. 1857, vol. xx. p. 423. The author shows that Diplodus is founded on the teeth of this genus.

Notwithstanding the endeavours of my distinguished friend Professor Ferd. Römer to clear up the ambiguous relations of the strata near Klein Neundorf *, the section appeared to me to be so very obscure that, even if the Ichthyolites found in the schists of that insulated spot had proved to be Carboniferous (which they are not, but, on the contrary, distinct Permian types), no satisfactory inferences could be drawn. There, to the south-west of the hamlet, schistose grauwacké, like the shillat of Cornwall, and probably of Devonian age, is observable in the ravines, between which and certain outcrops of Kiesel-Schiefer and amorphous crystallized limestone, and showing no visible connexion either with the Roth-liegende or Zechstein, lies the dark flaggy schist, used for slating, which contains Fishes and Plants. M. Sachse of Löwenberg obligingly accompanied me to the ground; and from him I obtained specimens of Acanthodes gracilis and other Fishes, all distinct, according to the latest examination, from Carboniferous species.

The opinion, therefore, of M. Beyrich, that the Roth-liegende should be classed with the Coal-deposits, receives the same refutation by a rigid appeal to the animal remains as it does from a thorough scrutiny of the vegetable contents of the deposit, as will be shown hereafter on the evidence of Professor Göppert.

In my last visit to Bohemia, in 1862, when accompanied by Dr. Anton Fritz of Prague, I made a special examination of the tract which, exclusively occupied by Permian rocks, lies between the fortresses of Königgrätz and Josephstadt on the south and the flanks of the Riesengebirge. This undulating country, which is traversed by the railroad from Pardubitz to Zwickau, was the scene of the great slaughter which recently took place in many combats between the Austrians and Prussians, and ended in the great battle of Sadowa. In this tract the Permian strata are represented by the Austrian geologists as being divided into no less than eight parts, each marked by a separate colour on their maps. Sandstones and conglomerates abound in the lower part, with shales and limestones with fossil Fishes like those to be mentioned at Liebenstadt in the central portion, and again sandstones in the higher, the whole being marked by powerful igneous masses, some of which were evidently contemporaneous with the strata, others posterior and intrusive †.

The immediate neighbourhood of Dresden has also proved to be very illustrative of the great mass of the Lower Permian rocks, under the able researches and classification of Professor Geinitz. Every geologist who visits the admirable collection in the Zwinger Gallery, still more if he has explored the tracts where the specimens have been obtained, will recognize the value of such a labour ‡.

The lowest portion of the Permian rocks of Dresden overlying the Coal which

* Zeitschr. Geol. Gesells. vol. ix. p. 51.

† For the description of this tract by myself, see Quart. Journ. Geol. Soc. vol. xix. p. 297 &c.

‡ In his instructive memoir on the Plants of the Roth-liegendes and Zechstein of Saxony (which deposits he has included, like myself, in the Permian group), "Die Leitpflanzen des Roth-liegenden und des Zechsteingebirges, oder der Permischen Formation in Sachsen," Dr. H. B. Geinitz, separating the Permian flora of the Roth- and Weiss-liegendes (as Gutbier and Göppert have done) from that of the Coal-period, and enumerating many peculiar species, specially illustrates (in two plates) the genera Palæophycus, Alethopteris, Hymenophyllites, Ullmannia, Guglielmites, Walchia, and Cardiocarpon.

My eminent friend Professor Geinitz, after he had adopted the term 'Permian,' thought fit to substitute for it the word 'Dyas,' thereby to express the fact that in Saxony the group is essentially composed of two formations, the Roth-liegende and the Zechstein. This term, however, like any other which is founded on numerical division, cannot be generally applied. Thus, in Russia the limestones form numerous bands, interlaced with marls and conglomerates. In many countries, indeed, the Permian is one mass of sandstones; in others, as in North-western America, it is one calcareous formation. I therefore dissented from the innovation of M. Marcou, which Professor Geinitz adopted (see Edinb. New Phil. Journ. 1862, vol. xv. p. 71, and Phil. Mag. ser. 4. vol. xxiii. p. 65); and I am now happy to find that the term 'Permian' is still generally used by geologists.

is worked is a grey conglomerate, made up of fragments of granite, quartz, and older rocks, including even those of the Upper Coal-strata, over the surface of which the deposit ranges transgressively. Schistose in aspect, and becoming reddish in parts only, this bottom Permian rock, which obtained its light colour from the breaking up of the whitish Upper Carboniferous Sandstone, contains indeed a few layers of Coal formed out of true Permian Plants, including the remarkable genus of Palm, Guglielmites Permianus (so named by Geinitz on account of its resemblance to the Guglielma speciosa of the Brazils described by Martius). With this Plant are associated Calamites gigas, Brongn., Walchia filiciformis, Sternberg, many Psaronites, and the great Araucarites Saxonicus, some of the silicified stems of which, ornamenting the above-mentioned splendid and instructive museum, have a diameter of 3 feet. Passing up through this lower zone, which has a thickness, in one shaft in the Plauensche Grund near Dresden, of about 320 feet, we come to the chief mass of the Roth-liegende, in this district between 500 and 600 feet thick, and perfectly conformable to the underlying grey rock. This mass is made up of the débris of all the more ancient rocks of the neighbourhood, including much lydian-stone, granite or granatite, gneiss, grey-wackè, and porphyry, some of the fragments being in fact gigantic, as seen near Tharande. This rock is also associated with bands of porphyry, which Geinitz, considering it to have been contemporaneously deposited with the conglomerates in the form of lava, has termed 'Schlamm-Lava.' This, though truly an igneous rock, is as regularly bedded and jointed as the red strata with which it alternates. In the same tract, indeed, as in many other parts of Central Germany, the dejections of porphyry and amygdaloid have been occasionally so mixed up with sand and pebbles of the then existing sea, as to render it difficult to decide whether the stratum should be referred to an aqueous or to an igneous origin.

Calcareous matter is here and there sparingly distributed; and a coprolite has been detected and described by Geinitz. A limestone band, occurring at Schereindorf in the Plauensche Grund, and lying between the upper and lower or grey member of the Roth-liegende, contains a few indistinct Bivalves and Fishes.

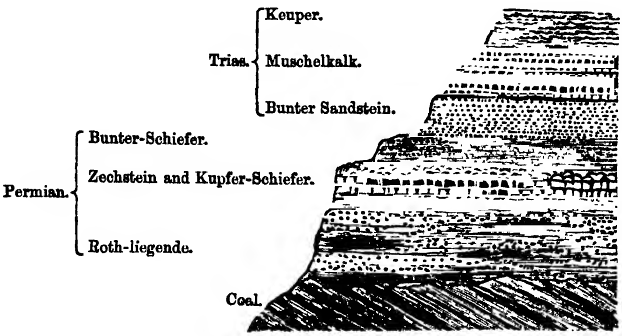
Of the numerous fossil Plants of these Permian deposits in the environs of Dresden, and thence extending over the adjacent tracts of Saxony and Bohemia, it is sufficient to state for the present that four or five species only are also known in the subjacent Coal-strata, thus completely sustaining the conclusions drawn by Geinitz and Gutbier * as to the independence of the Permian flora,—an inference which, as will presently be shown, has recently been amply confirmed by Göppert.

In taking a general view of the Permian rocks of Germany, we see that they differ chiefly from those of Russia, in their lithological divisions, by exhibiting a much more massive development of the lower member, or the Roth-liegende, over large areas, and in not having yet offered in their superior member, or the red beds above the Zechstein, those numerous Plants and Saurians which characterize the Upper Permian sandstone and conglomerates of Russia. On the other hand, by detecting in Germany many of the Plants in the red rocks below the Zechstein which in Russia lie in

* See 'Versteinerungen des Permischen Systemes in Sachsen,' Dresden and Leipzig, 1849. Out of sixty species of these Permian plants from Zwickau in Saxony, forty are exclusively of Permian age, and several are identical with forms from Russia, which there lie in strata above the Zechstein.

red rocks above that rock, all the members of the group are united by palæontological evidences.

In a general sense it may indeed be said that the Permian of Germany is a lower or palæozoic 'Trias,' the central mass of which is the Zechstein



with red sandstone above and below it; whilst the Upper or Secondary 'Trias' is also marked by its middle limestone, the Muschelkalk, with its underlying Bunter Sandstein and its overlying Keuper marls.

Whether the lower 'Bunter' be abstracted from the Trias or not, let me again call attention to the fact that, whilst the Permian and Trias are conformable to each other, and exhibit nowhere in Germany any of those disseverments which mark the separation of the Lower from the Upper Coal of the Continent, their respective fauna and flora are, according to the present state of knowledge, entirely dissimilar. The Permian exhibits the last traces of primeval life, whilst the Trias is charged with Secondary Plants and Animals entirely distinct from all those which preceded them.

Permian Rocks of Britain &c. (see No. 8 of the Map *).—The Permian rocks of Britain, where they are most clearly developed, consist, in ascending order, of the lower red and yellow sandstones and conglomerates, the equivalents of the Roth-liegende; the Marl-slate and Magnesian Limestone, the equivalents of the Kupfer-Schiefer and Zechstein; followed by certain bands of red sand and marl, as expressed in the preceding diagram. The best types, particularly of the calcareous or central portion of this succession, are to be seen in the counties of Durham, York, and Nottingham, where they were long ago admirably described by Professor Sedgwick †, and compared by him with the German deposits of like age. Let us therefore first treat of the group in those districts where the clearest relations of its chief parts are best exhibited.

In Durham the lower sandstone is well exhibited at Clacksheugh, three miles west of Sunderland, where, on the left bank of the Wear, its lowest portion

* The Permian rocks, as defined in the work on Russia, were first laid down on a Geological Map of England constructed by myself in 1843, and published by the Society for the Diffusion of Useful Knowledge (see also new editions, 1856 and 1866, published by Stanford).

† See Sedgwick on the Magnesian Limestone (Trans. Geol. Soc., 2nd series, vol. iii. p. 37).

is a dull-red sandstone *, lying far above all those strata in which traces of coal have been found. This red rock gradually assumes a mottled yellow and red colour, whilst, in ascending, the yellow colour exclusively prevails in the escarpment on the right bank of the river, where a soft yellow sandstone, about 100 feet thick, and in parts quarried as a freestone, forms the natural and conformable support of the mass of magnesian limestone, the structure of which has been well exposed by the cutting of a railroad. These red and yellow sandstones, absolutely dovetailed into each other by mineral characters, exhibit features which are not seen in the underlying Carboniferous rocks, and particularly in containing many laminæ of false-bedding; whilst their upper and harder courses, gradually becoming slightly calcareous, pass up into the thin flaglike strata constituting the base of the Magnesian Limestone: both rocks partake of the same flexures. The yellow sandstone with white incoherent beds, and an overlying marly flagstone, are traceable at intervals through the county of Durham, along the foot of the escarpment of the Magnesian Limestone by Sherburn and Ferry Hill, and have been traversed by numerous shafts of the more recently made coal-pits.

In numerous places the limestone is united to the sandstone by means of a flaglike marlstone, called Marl-slate by Sedgwick, who has shown it to be the equivalent of the Kupfer-Schiefer of Germany; it contains Lingula Credneri, Gein., and fossil Fishes of the genera Palæoniscus, Pygopterus, Cœlacanthus, Acrolepis, and Platysomus, with Plant-remains (Ullmannia).

The overlying yellow magnesian limestone is most fully exhibited in the bold line of coast-cliff extending from Sunderland to Hartlepool, where its lithological varieties and peculiarities, including large round concretions and beds of flexible sandstone, were completely described by Sedgwick †. In its range southwards through Yorkshire, this rock is characterized by Axinus obscurus, and, though lost for a certain distance under younger deposits some miles to the south of the Tees, becomes again an important formation between Doncaster and Nottingham. Formerly it furnished materials for the construction of the old cathedral churches of York, Beverley, and Ripon; and recently it has afforded the chief building-stone for the Houses of Parliament. The accuracy of the sections described by Professor Sedgwick so many years ago, in showing the relations of this limestone to the sandstone beneath it, and to certain red and occasionally sandy strata above it, as exposed in the southern parts of Yorkshire, has been demonstrated by the cutting of the railroad from Bradford to Doncaster. In that traverse, the observer, who proceeds from west to east, no sooner leaves the coal-field than he passes by, 1st, a thin band of lower red sandstone;

* English geologists will perceive that my views respecting the underlying red and yellow sandstone, passing up conformably into the Magnesian Limestone, are not in accordance with those proposed by Mr. R. Howse (Ann. Nat. Hist. 2 ser. vol. xix. p. 36), in which he unites these sandstones with the Carboniferous series. I do not admit that the occurrence of a few Plants said to be of Carboniferous species in the underlying red sandstone at Tynemouth affects my conclusions as to the true base of the Permian. In visiting both banks of the Wear near Clacksheugh, accompanied by Mr. Talbot Aveline, we saw proofs of such a gradual passage of the red sandstone into the yellow sandstone, and of the latter into the magnesian limestone, that I necessarily group them according to the classification of Professor Sedgwick. I am bound, however, to say that the memoir of Mr. Howse displays talent and assiduity, and must be considered a valuable contribution to the history of the Permian rocks and fossils.

† The reader who desires to become acquainted with the details of the structure and contents of the Magnesian Limestone and associated strata should consult the following works:—Sedgwick. Trans. Geol. Soc. 2nd ser. vol. iii. p. 37; King Monograph Perm. Foss., 1850, and Ann. Nat Hist. 2nd ser. vol. xvii.; Howse, *ibid.* vol. xix. Binney, Mem. Lit. & Phil. Soc. Manchester, vol. xii. and vol. xiv; Kirkby, Quart. Journ. Geol. Soc. vol. xvii. & vol. xx.; Tyneside Nat.-Club Transactions, 1866, &c. The six subdivisions, in ascending order, of Marl-slate, Compact Limestone, Magnesian Conglomerate, Shell-limestone, Botryoidal Limestone, and Upper Yellow Limestone, given by Mr. Howse and repeated by Mr. Davidson as the details of the Permian group (Palæontograph. Soc. Monograph, 1856), are here omitted. They are, in fact, merely local subdivisions of the Magnesian Limestone of Durham, and altogether form the calcareous or central part only of the natural group defined as Permian in Russia and Germany by myself and associates.

2nd, a great mass of the thick-bedded magnesian limestone; 3rd, a zone of red marl with gypsum; 4th, the thin-bedded limestone so largely worked in Yorkshire, and which, containing traces only of magnesia, is preferred for agricultural purposes; and, 5th, red sands and marls, which range up to the town of Doncaster, and form the summit of the whole group. But, to return to the consideration of the basement-rock of the group.

Obscured by overlying formations and detritus in the North Riding of Yorkshire, the red and yellow sandstones emerge in force between Ripon and Knaresborough, and under the Castle at the last-mentioned place are surmounted in a striking cliff by the Magnesian Limestone, precisely in the same manner as in Durham, the lower part of the yellow rock being underlain by a thick-bedded, deep-red, hard, sandy grit. In this district, indeed, and particularly on the banks of the Nid near Knaresborough, the inferior red member rises up in marked and distinct physical masses, which there merge into an angular and subangular quartzose conglomerate, undistinguishable from the Roth-liegende of the Germans. Whilst revisiting these scenes of my youth in the autumn of 1857, in company with Mr. Aveline, immediately after a tour in the Thüringerwald, Harz, and Bohemia, I had no hesitation in affirming that the well-known picturesque 'Plumpton Rocks' near Harrogate are identical with the quartz-conglomerates of Germany (pp. 316 &c.), whether as regards their ingredients, colour, false-bedding, or massive stratification.

In tracing the lower sandstones southwards through Yorkshire, they are seen to be quarried in many places to the west of Bramham Moor; and at Pontefract they are largely worked. There the yellow 'Pontefract rock'* is again clearly seen, as in Durham, to form the natural base of the Magnesian Limestone.

The lowest visible beds at Pontefract are also occasionally of a red colour; but the great mass of conglomerate and breccia, as exposed in the Plumpton Rocks, is no longer to be detected, the bottom beds being simply hard, deep-red, flaglike, micaceous grits †. These are surmounted by yellow sandstones, in parts of whitish colours, which are extensively used as building- and trough-stones, some portions being so porous as to make excellent filters. Occasionally, indeed, the stratum is so incoherent as to be used only as scouring-sand.

To the south of Pontefract the lower sandstones, both red and yellow, begin to thin out; and, though they are recognizable on the banks of the Don, and under the Castle of Conisborough, the band is greatly reduced in thickness, and exhibits little more than a reddish, micaceous, flaggy rock, with shale &c. Still further to the south, this lower sandstone, as exposed on the eastern side of the Pennine chain, and to the east of the South Yorkshire Coal-field, is diminished to a mere bed, which expires altogether in the environs of Nottingham. There the Magnesian Limestone rests at once upon the Coal-measures.

Thus this lower member of the Permian group, as seen on the eastern side of the Pennine chain, exhibits, though on a less scale, the chief peculiarities of its ...rman equivalents. In one place a fine sand, in another a coarse grit, in a third a breccia or conglomerate, and always varying much in dimensions, it has evidently been formed on the eroded surfaces of the preexisting Carboniferous rocks. But however variable in thickness it may be, as depending upon the method of accumulation, we invariably perceive that its upper beds graduate into and form the natural bottom of the Magnesian Limestone, as formerly

o me.

† The clear and careful paper by Mr. Binney, ... tion, but does not alter my opinion.

demonstrated by Sedgwick *. In the sequel it will be seen how greatly this lower member of the Permian group is expanded on the western flank of the Pennine chain.

Professor King, who had long studied the fossils of the calcareous members of the group in the county of Durham, placed the detailed component parts of the Permian group still more closely in comparison with the corresponding beds of Germany. Thus, whilst, with Sedgwick, he considers that the lower sandstones of Yorkshire and Durham, whether red, white, or yellow, which lie between the Coal and the Magnesian Limestone are the true equivalents of the German Roth-liegende, and that the Marl-slate, with its Fishes, stands in the place of the Copper-slate of Germany, he also shows that the fossiliferous beds † of compact limestone represent the Lower, and the brecciated and concretionary limestones of Durham the Upper Zechstein of the Germans, with its overlying beds of Dolomite, Rauchwacke, and Stinkstein.

In England there is, perhaps, no other yellow limestone so charged with magnesia as to form a true dolomite; and hence, in the early days of geology, it was natural to define this rock as *the* Magnesian Limestone ‡, and to associate with it certain subordinate strata. But now that yellow magnesian limestones are known to occur, on a stupendous scale, in the Lower Silurian rocks of North America §,—in both the Devonian and Carboniferous series of Russia,—partially even in the Carboniferous Limestone of Derbyshire and Ireland,—and whilst the Jurassic masses of the Alps are to a great extent crystalline magnesian limestones or dolomites ‖,—it became necessary to abandon the term 'magnesian,' and to place the English formation under a general name derived from a vast region where the position and fossil contents of the group are clearly exhibited.

The Permian deposits, as developed in Russia, and also in Germany and England, do not stop, as before said, in the ascending order with the Zechstein. They include another overlying red sandstone, which in many parts of Germany, as already shown, also constitutes the conformable roof of the Zechstein, and contains the plant Calamites arenaceus, Jäg., with its Carboniferous aspect. In Russia, indeed, some of these overlying red beds are charged, as we have seen, with the Shells of the Zechstein and Plants of the Roth-liegende. In general language, therefore, the Zechstein of the Continent, and the Magnesian Limestone of England, may be viewed as the calcareous centre of an arenaceous group, or, as before said, a lower 'Trias,'—the upper red marl and sand of Yorkshire, described by Sedgwick, being as much a parcel of it as those red sandstones and conglomerates, or 'Roth-todt-liegende,' which in Western Europe lie beneath it.

In some tracts these latter rocks, so diversified elsewhere, are represented by a band of siliceous conglomerate, so poor in fossils that, with the New Red and Vosges Sandstones, the Zechstein, and Kupfer-Schiefer, they were named

* See Sedgwick on the Magnesian Limestone, Trans. Geol. Soc. Lond. 2nd ser. vol iii. p. 37.

† See Prof. King's 'Monograph of the Permian Fossils of England, published by the Palæontographical Society, 1850, in which he describes 217 species of Shells, Corals, and other animals, many of them common to Germany and Russia.

‡ I am, however, disposed to think that some of the yellow beds of the Carboniferous Limestone of the Clee Hills are exceptions (see Sil. Syst. p. 119). The dolomitized Carboniferous Limestone of the south of Ireland, described by Professor R. Harkness (Quart. Journ. Geol. Soc. vol. xv. p. 100), is also to be borne in mind.

§ See Dale Owen's Geology of Wisconsin, Iowa, and Minnesota, with a Map, on which vast magnesian limestones are laid down as the Lower Silurian of that author. 1853.

‖ True dolomite, whether crystalline or earthy, is known by its containing 45 per cent. of magnesia. Another proof of the inapplicability of mineral terms to designate the age of strata is the use of the term 'oolitic' for rocks which in England have a lithological structure that is scarcely ever found in their continental Jurassic equivalents. 'Magnesian Limestone' is also merely an insular and misleading name.

'*Pénéen*' by M. d'Omalius d'Halloy *. In France (*i. e.* in the Vosges, and at Lodève in Dauphiné) this group has not the distinctive characters, lithological or zoological, which it exhibits in Russia, Germany, and Britain, being chiefly a red sandstone. But in the Department of L'Aveyron (particularly in the neighbourhood of Alboy) it has been described as containing some calcareous courses representing the Zechstein †. In that tract it is also distinguished, as in other regions, by a peculiar flora, containing certain Ferns and Conifers which M. Adolphe Brongniart classes with Permian plants.

In proceeding from the northern to the central and south-western counties of England, or, again, to the south-west of Scotland, the Permian group undergoes also considerable changes in lithological structure, and with the absence of limestone is accompanied by a diminution of the number of its characteristic organic remains. In Nottinghamshire, and to some extent in Derbyshire, limestone being still present, the north-eastern or Durham type is preserved; but at Manchester we no longer distinctly trace the Magnesian Limestone as a separate mass, though its place is taken by red marl and shale, with some thin courses of limestone subordinate to red sandstone, in which are casts of the common species of Schizodus, Avicula, Turbo, Rissoa, &c.,—an unmistakeable Permian assemblage.

Following the formation into the north-western counties from the tracts in Lancashire, where he has copiously exhibited its relations to the Coal beneath, and to the New Red Sandstone above, Mr. Binney ‡ has estimated the maximum thickness of the group in that region at 1160 feet, viz.: Red marls with gypsum in the north, and nodules of limestone in the south, 300 feet; Magnesian Limestone with fossils, 10 feet; Red Sandstone, 500 feet.

Professor Harkness and myself have demonstrated the existence in Westmoreland of a range of the Permian rocks of great thickness in the valley of the Eden. There the lowest band consists of the Penrith Sandstone, surmounted by calcareous breccias, the middle part of impure limestone and shale with Plants identical with those which lie in the Marl-slate beneath the Magnesian Limestone of Durham, and of massive overlying red sandstones with gypsum §. The latter are of great thickness in their range to Corby Castle, and also at St. Bees Head, where they overlie a very thin course of Magnesian Limestone with fossils. To the north of this point no Magnesian Limestone, or Zechstein, has been seen; and when the Permian rocks range into Scotland they become one vast mass of sandstones overlying the coal-formation. I suggested, indeed, many years ago ‖, that the sandstones of Corncockle Muir, near Dumfries, so celebrated as exhibiting the footprints of the large Sauroid and other Reptilian animals, illustrated by Sir W. Jardine ¶, would fall into this category **. The importance of thus working out the clear definition of the rocks which really pertain to this upper member of the Palæozoic series will be more apparent at the close of this Chapter, when we enumerate all the classes of fossil animals which are known to be of Permian age.

It is also now ascertained that much of the red rock which overlies the coal of Ayrshire is of Permian age ††, as well as those red sandstones in the southern

* Elémens de Géologie, p. 277: 1831.

† See the memoir of M. Coquand, Bull. Soc. Géol. de France, série 2. vol. xii. p. 128.

‡ Memoirs of the Lit. and Phil. Soc. of Manchester, vol. xii. Session 1854–55.

§ See Quart. Journ. Geol. Soc. vol. xviii. p. 205, and vol. xx. p. 144.

‖ See Quart. Journ. Geol. Soc. vol. vii. p. 163, and vol. xii. p. 267.

¶ See Sir W. Jardine's 'Ichnology of Annandale.' Some of the tracks have been referred to Batrachian, and others to Chelonian reptiles.

** Mr. Binney also came to the same conclusion some years ago (1856): Quart. Journ. Geol. Soc. vol. xii. p. 138.

†† Binney, Quart. Journ. Geol. Soc. vol. xviii. p. 439.

part of the Isle of Arran which Sedgwick and myself classed as New Red Sandstone at a period when the Permian classification was unknown. Recently Mr. Geikie has ascertained that subordinate to the lowest zone of the Permian rocks of Ayrshire there are beds of cotemporaneous igneous rock,—a point of exceeding interest in showing that in parts of Britain, as throughout Central Germany, volcanic evolutions were frequent in the period of the Lower Permian.

Professor Harkness and myself have also expressed the opinion that the valuable hematite which often occurs in a breccia at the base of the Permian rocks of Cumberland was formed at the commencement of this era, so marked by the great changes which occurred after the Carboniferous era. This observation is one of great interest; for it demonstrates that in our own country there exist the same evidences of igneous activity in this epoch, particularly in its earlier part, which are so common in the Roth-liegende or Lower Permian of Germany. The accompanying woodcut, drawn by Mr. Geikie, explains the phenomena which occur in Ayrshire, where submarine volcanic action has manifestly occurred during the accumulation of the Permian rocks, all the deposits having long afterwards been penetrated and traversed by eruptive greenstones:—

SECTION ACROSS THE PERMIAN BASIN OF AYRSHIRE.

f. Intrusive greenstone (dolerite) coming through the Permian trap-rocks. *e.* Brick-red sandstones. *d.* 'Necks' of Volcanic agglomerate, of Permian age. *c.* Beds of felspathic amygdaloidal trap with interbedded brick-red Permian sandstones. *b.* Trap-tuff and brick-red ashy sandstone of Permian age. *a.* Upper Carboniferous sandstones and shales.

"The brick-red Permian sandstones of the Ayr (*e*) occur in a basin about six miles long and four or five miles broad. This basin is completely encircled with a ring of igneous rocks (*b*, *c*), which lie upon the upper red part of the Coal-measures (*a*) and form the base of the Permian series. They consist of dark-brown, purple, or chocolate-coloured porphyries or melaphyres, often highly slaggy and amygdaloidal, and of coarse volcanic agglomerate, and fine gravelly tuff, mingled with the ordinary red sediment of the Permian sandstones. That these volcanic rocks belong to the Permian series is shown by the fact that (containing beds of the usual sandstone of that series, which differs conspicuously from the red sandstones of the underlying Coal-measures) they are regularly interstratified with the base of the Permian group. Around the outside of the volcanic ring occur numerous round hills and hillocks of coarse volcanic agglomerate (*d*). These are true 'necks,' which descend vertically through the Coal-measures, altering the coal-seams. They are some of the orifices from which the melaphyres and tuffs were ejected. Igneous rocks of similar character occur in the Permian basin of the Nith, north of Thornhill, and probably in other parts of that basin*. It may, in the end, be ascertained also that many of the igneous masses which perforate the Carboniferous rocks along the wide central valley of Scotland are likewise of Permian age."

* See 'Geological Magazine' for June 1866.

Reverting to England, I may say that I cannot readily abandon the opinion I formed after many years of personal researches, that the trappean agglomerates of the south of Devonshire may be of Permian age. I admit that Mr. Pengelly has endeavoured to show, and with much ability, that these red rocks, extending from the west of Torquay to Dawlish, form the natural base of the Trias, which underlies the Lias to the east of the River Exe; but I must be permitted to doubt whether, considering the great intervening estuary of the River Exe, there may not be some unconformity—some overlap of the younger and Infra-Liassic strata, as respects these lower breccias. I can only say that I entirely agree with Conybeare and Buckland, who, after a journey in Germany in 1816, distinctly identified the Heavitree Conglomerate near Exeter with the Roth-liegende of the Germans †. Long before that, indeed, Dr. Berger had admirably described these rocks; and any one who may read his description ‡ will see how very different they are from any band of the Trias either in Germany or Britain. Again, in 1839, Sir H. De la Beche § described these rocks as of igneous origin and interpolated among the red sandstones and conglomerates. Now, as we are unacquainted with signs of volcanic activity in the Trias, and have seen that it abounded in the beginning of the Permian era, I must, until more evidence shall have been brought forward, remain in the persuasion that these lower red rocks of Devonshire may represent the Roth-liegende of Germany and the 'Lower New Red Sandstone' of the older English geologists.

In the endeavour to trace the Permian rocks to the south of the Manchester tract, we lose the clear evidence of the fossiliferous limestone centre, though calcareous conglomerates and breccias do occur above the Lower Red Sandstone and may probably be viewed as representing the Magnesian Limestone of the northern counties. Such, at least, was my opinion when I described these rocks many years ago, particularly as exhibited in Shropshire, Staffordshire, and Worcestershire. In those tracts the Lower Red (erroneously called the 'Lower New Red' before the term 'Permian' was proposed) is an arenaceous formation of considerable dimensions, which, as I then showed, had been very successfully bored through in search of coal (Sil. Syst. p. 58). To the south of the Staffordshire Coal-field, such Permian strata are seen to rest on the Upper Carboniferous beds.

In that district calcareous matter so abounds in the red Permian rocks as to constitute zones of earthy subconcretionary limestone, which we pointed out as being undistinguishable from cornstones of the Old Red Sandstone of the adjacent county ‖. Thus, lying between two red deposits of similar structure, the position of the coal of Staffordshire and Shropshire realizes the aphorism of Humboldt, "que le terrain houiller n'est qu'un accident dans le grand terrain du grès rouge."

The irregularity of succession between the Coal and these Permian rocks has been defined by Mr. J. Beete Jukes as occurring around the South Staffordshire Coal-field; and on the left bank of the Severn, between Enville and the Forest of Wyre, the whole of the Permian series is represented by Professor Ramsay ¶ as shown in the following diagram (p. 334), in which we see the Coal-strata, *a*, lying at an angle beneath the unconformable red sandstone, *b*, with calcareous courses and concretions, and how both deposits have been downcast by a great fault, *. We further observe the order of the Permian rocks in this tract to consist of, *b*, sandstone, marl, calcareous courses, and conglomerates beneath,

† Geology of England and Wales, p. 313.
‡ Trans. Geol. Soc. vol. i. p. 99.
§ Report on the Geology of Devon and Cornwall, pp. 199 *et seq.*
‖ Silurian System, p. 55. Also Mr. J. Beete Jukes, in Records of the School of Mines, vol. ii. pp. 160 &c.
¶ Quart. Journ. Geol. Soc. vol. xi. p. 188.

overlain by a breccia, *c*, charged with fragments of igneous rocks. Above the last-mentioned are the highest beds of the Permian group in this quarter, consisting of red sandstone and marl, *d*,—the whole series being crowned by unconformable beds of other red sandstones and conglomerates, *e*, *f*, which constitute the lower members of the Trias or New Red Sandstone.

SECTION OF THE PERMIAN ROCKS BETWEEN THE COAL OF THE FOREST OF WYRE AND THE NEW RED SANDSTONE OF ENVILLE.

a. Coal-measures. *b*, *c*, *d*. Permian rocks (*b*, sandstone and red marl with two beds of calcareous conglomerate; *c*, course breccia; *d*, sandstone and red marl). *e*, *f*. Bunter Sandstone (*e*, lower brick-red or variegated sandstone; *f*, pebble-beds or conglomerate). *. Fault.

At Alberbury and Cardiston in Shropshire, a calcareous conglomerate overlying the Lower Red Sandstone, and dipping under other red strata, assumes so much the character of a bedded though brecciated limestone, and also contains so much magnesia, that I still consider it to be probably the equivalent of the Zechstein (see Sil. Syst. p. 63).

In advancing from the centre towards the South of England, one member only of this group of rocks is exposed, besides the doubtful rocks of South Devon. Thus the peculiar hills that range along an axial line from Abberley to Malvern, and which, on account of the vast quantity of igneous materials contained in them, I formerly considered to be of eruptive origin, have since been proved by Professor Phillips † to be a reaggregated trappoid breccia. Professor Ramsay ‡ has shown that this rock is of the same age as the breccia, *c*, of the diagram above, and that, besides felspathic and porphyritic materials, it contains subangular blocks and fragments of old slaty rocks, mostly derived from the Longmynd Mountain in Shropshire, and the rocks of the adjacent country of Shelve, described in the Second and Third Chapters of this work. The exact place of these breccias in the Permian series, which there separate the Old Red from the New Red Sandstone, will be eventually defined by the Government Surveyors, who will also precisely coordinate the other varieties of this British group, whether they be the red, yellow, and white sandstones overlying the Coal and supporting the Magnesian Limestone, or the varied equivalents of that rock and its overlying red and sandy marls &c.

In parts of their range, through the central counties, the Permian rocks have been found to contain Plants. At Allesley, for example, near Coventry, such fossils have long been known as existing in a highly silicified state, like that of the stems in the Roth-liegende of Germany.

The rock in which these Plants occur has been separated from the New Red Sandstone, with which it was formerly classed, through the detailed examination of Professor Ramsay and his associates. Indeed, in the sheets of the Survey Map explanatory of the structure of those central tracts, much of the red sandstone which ranges up to near Warwick is shown to form part of the Permian series of rocks, even some casts of certain Permian Shells having been found near Exhall. The best fossiliferous British types of the Permian group are,

† Mem. Geol. Surv. vol. ii. pt. 1. p. 112.

‡ Quart. Journ. Geol. Soc. vol. xi. p. 155.

however, only to be seen in the counties before enumerated, which lie to the north of the River Trent.

In the north of Ireland the true equivalent of the Magnesian Limestone—similar in mineral character and in fossils to the rock in Durham and Yorkshire—has been recognized. A small patch of it, occurring at Cultrea, on the south side of the Bay of Belfast, was first noticed by Mr. James Bryce*; and subsequently the fossils were described by Prof. King as species of Schizodus, Mytilus, Arca, and Pleurophorus. Afterwards the latter author, examining another fossiliferous locality † (Tullyconnel Hill, near Artrea, in Tyrone), observed that the parent rock was a sandy dolomite which, like that at Belfast, overlies the Carboniferous Limestone, and seems to dip under red sandstone. Among the thirteen species of fossils from Artrea, described and figured by King ‡, Mytilus squamosus, Bakevellia antiqua, Schizodus obscurus, Pleurophorus costatus, and Turbo helicinus are common to the deposits of the same age in England and the Continent, including the far north-eastern Petschora-Land of Russia, whence some of those species were brought by my associate Keyserling. The other forms, including Corals and Polyzoa, abound in the Magnesian Limestone of England. Thus it is now ascertained that the sea in which those peculiar animals flourished extended from the eastern to the western extremity of Northern Europe, or over a breadth of about 2500 miles! §

In comparing the Permian deposits of England with those of Germany, it is worthy of remark that, when examined from north to south, the mineral masses are, on the whole, found to succeed each other in a similar manner in the two countries. Thus, in the English northern counties, it is only in Cumberland, Durham, Yorkshire, and Nottinghamshire that we meet with the true Magnesian Limestone, or Zechstein, and its associated fossils; whilst in Lancashire, Shropshire, Staffordshire, Worcestershire, and Warwickshire the whole group is represented as in Southern Germany and Russia, by red sandstones, marls, breccia, and conglomerate, with occasional traces only of calcareous matter. The most striking phenomenon, however, in regard to this natural group in Great Britain, is its very dissimilar lithological character on the opposite sides of the central axis of the country. On the eastern side the Magnesian Limestone is the dominant feature, with an irregular and evanescent equivalent of the Roth-liegende and a meagre capping of red and sandy marl. On the west the lower or arenaceous member of the group is largely spread out in Staffordshire, Shropshire, and Lancashire; and there the limestone is for some distance only represented by certain calcareous marls near Manchester. The researches of Mr. Binney have clearly shown how these sandstones, marls, and conglomerates are related to the underlying coal, and how they extend northwards into Scotland; and Professor Harkness and myself have described the vast thickness of the lower division in Westmoreland (near Penrith), with a central representative of the Zechstein or Magnesian Limestone, and a full Upper

* Journal of the Geological Society of Dublin, vol. i.

† The late General Portlock had formerly transmitted fossils from this locality to Dublin.

‡ 'On Irish Permian Fossils,' Journ. Geol. Soc. Dublin, vol. vii. pl. 1.

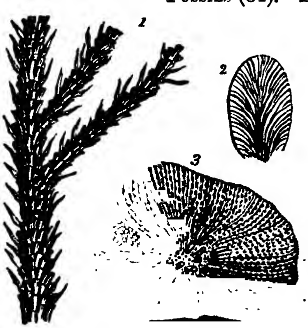
§ Permian fossils have also been discovered in Texas, in beds overlying coal-deposits.

Permian series in both Cumberland and Westmoreland—a feature almost entirely wanting in the range of the group from the Wear to Nottingham.

Permian Fossil Remains.—The fauna and flora of the Permian rocks are, as before stated, essentially palæozoic; for, whilst in great measure they are specifically distinct from those of the Carboniferous system, the amount of agreement in the two groups is surprising when we reflect upon the phenomena adverted to in the opening of this Chapter, of great physical revolutions which pretty generally affected the known surface of the earth at and before the close of the preceding or Carboniferous era. Those disruptions, therefore, however violent and extensive, were not universal, but were, we may suppose, so accompanied by new physical conditions as to occasion the destruction of many species of plants and animals.

1. *Flora.*—The Permian flora has not yet been so developed in the British Isles as to show in what degree it differs from that of the Carboniferous group, to which, in fact, it everywhere bears a resemblance; Mr. Howse, indeed, has said that some of the species found in the red sandstones of Tynemouth are identical with Coal-plants. At Ashby de la Zouch, Sternbergia has been detected, together with silicified wood, by the Rev. W. H. Coleman; whilst the researches of the Geological Survey have shown that much of the red rock of the Central Counties, formerly called New Red Sandstone, is of Permian age, and that among these masses must be included the rock of Allesley near Coventry, which has afforded many silicified stems of Plants. Professor Sedgwick* long ago pointed out the traces of Calamites in the Lower Red Sandstone, and various specimens collected by him and other geologists belong certainly to Carboniferous genera, as in other countries; but scarcely any of those which have fallen under my observation are sufficiently well preserved to afford specific characters. In those beds, however, which are subordinate to the Magnesian Limestone, the forms are so well preserved that there is no difficulty in distinguishing them, as in the accompanying figures of two fragments of plants found in the Marl-slate, from Professor King's 'Monograph of Permian Fossils,' 1848.

FOSSILS (84). PERMIAN PLANTS AND POLYZOAN.



1. Ullmannia selaginoides, Sternberg. 2. Neuropteris Huttoniana, King. Both are from the Marl-slate of Durham. The first has also been detected, with other fossil plants, in the Permian shales of Westmoreland, which occur in the middle of the series (see p. 331). 3. Fenestella retiformis, Schlotheim; Magnesian Limestone of Humbleton Hill. (The figures 1 and 3 are much reduced.)

In certain foreign tracts, however, which have been examined in detail, the Permian strata contain many more Plants. The sandstone of Lodève, before adverted to, affords, according to Ad. Brongniart, Ferns of the genera Sphe-

* Proc. Geol. Soc. vol. i. p. 344. Calamites occur also near Exhall, and in the Magnesian Limestone near Sunderland and the Marl-slate near Tynemouth.

nopteris, Pecopteris, Neuropteris, Alethopteris, and Callipteris, with Annularia floribunda (Sternberg), and several Conifers of the genus Walchia *. The sandstone and conglomerates (Roth-liegende) near Zwickau, in Saxony, rewarded the researches of Colonel Gutbier † with about sixty species of Plants. A few of these only are known in the Carboniferous epoch, the greater number of the species being unknown in any other deposit. Among the Plants most characteristic of the group may be mentioned Sphenopteris erosa, S. lobata, and the great reed-like Calamites gigas. Whilst in Russia these species of plants are chiefly found above the limestone courses, they are in Saxony confined to the lower strata, and are there commingled with some species known in the Upper Coal-deposits. The large silicified stems of Tree-ferns, called Psaronites, so much admired by collectors for the exquisite conservation of the fibre of the plant, and for the beautiful polish they take, occur abundantly in the Permian beds of Germany ‡.

On the whole, it was the opinion of Adolphe Brongniart, to whom the Plants brought from Russia (occurring there in red sandstones and marls above, or interlaced with, fossiliferous Zechstein) were referred, that they exhibit a continuation of vegetable life with characters to a great extent like those which prevailed in the Carboniferous era. But, whilst a few of the forms are generically the same as those of the Coal-period, the species, with very few exceptions, are different §. On the contrary, no one of the Russian Permian genera (Neuropteris, Odontopteris, Sphenopteris, Nœggerathia, Lepidodendron, &c.) occurs in the overlying Trias, in which, notwithstanding the clear proofs of conformity and mineral passage between the two groups, the geologist has before him an entirely different flora.

Thus Professor Göppert has enumerated from the Roth-liegende and Kupfer-Schiefer of Germany, and in the Permian rocks of Russia, 182 ‖ species of plants, of which 169 occur in the Roth-liegende alone, or lowest member of the group. This accomplished botanist favoured me with the following account of the number of species in this group, viz.:—Fuci, 2; Equisetaceæ, 5; Calamites, 10; Filices, 97; Lycopodiaceæ and Lepidodendraceæ, 11; Walchiæ, 5; Gramineæ (doubtful); Nœggerathiæ, 4; Palma, 1; Asterophyllites, 6; Annulariæ, 3; Sigillariæ, 2; Cycadeæ, 9; Coniferæ, Cupressaceæ, and Abietaceæ, 20; fruits undetermined, 6.

The essential result of this examination is, that, in comparing the Permian flora of Germany with that of Russia, Göppert finds a very close resemblance between the Plants extracted from the underlying Roth-liegende of various German tracts ¶ and those obtained from the strata in Russia, which, as before observed, lie chiefly above, or are intercalated with courses of, the Zechstein. Thus, with the species of the genera Neuropteris, Odontopteris, Callipteris, and Walchia transmitted from Russia, Göppert has identified twenty species of his Silesian and Bohemian collection. Hence the importance of a comparison which demonstrates the unity of the group over so wide an area.

Again, he observes that certain species of Walchia, particularly Walchia pisi-

* See 'Russia-in-Europe,' vol. i. p. 219.

† Geinitz und Gutbier, 'Gæa von Sachsen,' 1843. For the figures of these Plants, and sections showing their position, see Geinitz's 'Das Permische System in Sachsen,' 1850.

‡ The finest collection of these 'Psaronites' extant, with which I am acquainted, was that of my late friend, the eminent botanist, Robert Brown. They are now in the British Museum.

§ See 'Russia-in-Europe,' vol. i p. 219, where Brongniart names eleven species from these Russian beds as belonging to the genera Neuropteris, Odontopteris, Pecopteris, Sphenopteris, and all distinct from any of the forms in the Coal.

‖ In this number, 182, are included the two or three Plants only of the British Magnesian Limestone with which M. Göppert was acquainted.

¶ Not only those enumerated by my associates and self in our work on Russia, but also specimens transmitted to M. Göppert by M. Eichwald and Major Wangenheim v. Qualen.

formis, with Callipteris (Neuropteris) conferta, Odontopteris obtusiloba, Pecopteris Gœpperti, Morris and Brongn., Adiantites prisca, Fisch., Gleichenites Gœpperti, Fisch., and Calamites gigas, Brongn., are so widely diffused and so clearly recognized in many countries as of Permian age, that they may truly be considered types (Leit-Pflanzen). To these may be added Sphenopteris erosa and S. lobata as being also very characteristic. It is indeed admitted that this flora is, to a great extent, composed of the same families and genera as that of the Carboniferous epoch, and that Ferns and Calamites prevailed equally in both periods; yet, when we come to the details, about eight per cent. only of the Permian Plants are found to be specifically the same as those of the Carboniferous era; whilst the Psaronites are, according to the late distinguished botanist Robert Brown, Permian types only.

Again, while the Permian flora is generically connected with that of the antecedent but distinct formation, none of its Plants save one, Voltzia heterophylla, is known to have lived on into the succeeding or Triassic formation, or base of the Secondary rocks.

After balancing the whole of the botanical evidence, Göppert concludes, with Brongniart and Morris, that this flora, whether composed of the Plants of the Roth-liegende, or those of the Zechstein and overlying beds in Russia, differs from all other fossil floras, and marks strikingly the close of the Palæozoic times, of which it retains the family impress, whilst it is rigidly separated from all the vegetable products of Secondary age.

2. *Fauna.*—The chief Permian animal-remains bear a strong resemblance to their congeners of the Carboniferous era. When the work on Russia was written, my companions and myself were not aware of more than 166 Permian species; but, by the publication of the works of Geinitz, von Schauroth, and others, in Germany *, and of King, Howse, and Kirkby in England †, this number has been increased to 350 and more; still it is small in proportion to that of the preceding or Carboniferous epoch, about 1100 species of animals obtained from the Carboniferous formations having been already described.

The Permian limestones of England, Ireland, Germany, and Russia, are often rich in the remains of minute animals of the Rhizopodous and Crustacean classes, and which are not, in many cases, far removed from Carboniferous forms: 34 species belonging to these classes have been described. The plate illustrating M. Richter's memoir on the Thüringian Zechstein, in the 7th volume of the Journal of the German Geological Society, presents a characteristic group of these little fossils ‡. There is, however, a tiny creature not shown there, which was first noticed by Schlotheim under the name of Serpula pusilla. This has been shown by Rupert Jones § to be a Rhizopod (as Prof. King had suggested). It occurs in countless numbers in the black Zechstein of the Voigtland, and in the Magnesian Limestone of Sunderland, of Nosterfield in Yorkshire, and of Tyrone.

The Polyzoa and Corals have the aspect of the Palæozoic types, the small Cup-coral Calophyllum apparently showing the quadripartite arrangement of

* Geinitz, 'Die Versteinerungen des Deutschen Zechsteingebirges,' 1828; 'on Conularia Hollebeni,' Zeits. Deutsch. Geol. Gesells. vol. v. p. 465, and Steinkohl. Sachsens; 'Die animalischen Ueberreste der Dyas,' Leipsic, 1861. The memoirs of von Schauroth (Zeits. Deut. Geol. Ges. vol. vi. p. 539; and vol. viii. p. 211) have been published since the issue of the first edition of this work, and have added many new species.

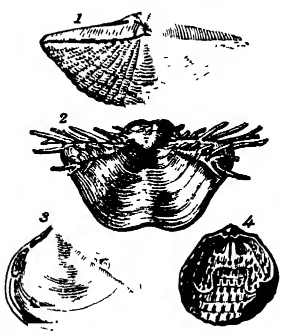
† Ann. & Mag. Nat. Hist.; Quart. Journ. Geol. Soc.; Trans. Tyneside Nat. Club; &c.

‡ Compare the Rhizopoda and Entomostraca figured and described by Rupert Jones in King's Monog. Pal. Soc. 1848, by Reuss in the Jahresb. Wetterauisch. Ges. 1851, and by Richter, *loc. cit.*; also the Entomostraca from Russia, Keyserling, Schrenk's Reise arkt. Ural, and the memoirs by Jones and Kirkby in the Transact. Tyneside Nat. Club. vol. iv. pp. 122–171.

§ Journ. Geol. Soc. Dublin, vol. vii. p. 73.

the lamellæ characteristic of the Cup-corals of the old rocks. The abundant Fenestella retiformis, Foss. 84. f. 3, and Synocladia virgulacea, are also of a type peculiar to the primeval fauna. Crinoids are rare; but there is in England a species of the genus Cidaris, the earliest known representative of the modern Sea-urchins *. The Brachiopods offer many Producti analogous to, but chiefly distinct from, those of the Coal-period, and number about twelve species, including Productus horridus and P. Cancrini, the former being the most common Permian shell in Britain and Germany (Foss. 85. f. 2). These very species (Productus horridus and P. Cancrini), with Spirifer alatus and Sp. cristatus?, have been found in blocks of limestone at Spitzbergen, and are described in detail by de Koninck. Of the genus Spirifer, Sp. alatus (f. 1) is the most characteristic; and Sp. cristatus is supposed to be common to the Carboniferous and Permian rocks. Of the genus Orthis, which prevails so greatly from the Lower Silurian to the Carboniferous inclusive, we here find no trace; it is represented by Streptorhynchus pelargonatus, Schloth., and other species. The genera Strophalosia (King) and Aulosteges (Helmersen) are more especially characteristic of the Permian system: the former occurs in Germany, England, and the United States; the latter is confined to Russia. Of the few species of Terebratula which are known, two or three are exceedingly abundant, and one, T. elongata of Schlotheim, can scarcely be distinguished from a common Carboniferous species. Athyris Royssii is supposed to be identical with the Devonian and Carboniferous shell (see 1st Edit. of Siluria, p. 308); but my friend Keyserling considers it to be a distinct type, which he has named Terebratula Royssiana, and he has figured it in his memoir descriptive of the fossils collected by the botanist Schrenk †.

FOSSILS (85). PERMIAN SHELLS.



1. Spirifer alatus, Schl. 2. Productus horridus, Sow. 3. Schizodus (Axinus) obscurus, Sow. 4. Strophalosia lamellosa, Geinitz. (All from the county of Durham. These species, except, perhaps, the Schizodus, are equally common in Germany and Britain.)

[The figures are about half the natural size.]

The genus Pentamerus, so characteristic of the Silurian epoch, but rare in the

* The species of Cidaris often quoted from Carboniferous rocks, belong, as has been well shown by M'Coy, to a different family. They are now termed *Archæocidaris*. See Ann. Nat. Hist. ser. 2. vol. iii. p. 352. They have been found also in the Devonian rocks by Sandberger.

† "Paläontologische Bemerkungen von A. Graf Keyserling," in A. G. Schrenk's 'Reise zu der Samojeder und zum arktischen Uralgebirge,' zweiter Theil, 1854.

This memoir, prepared in 1848, was not published until 1854, and hence some of the nomenclature has been set aside for other names. The work is highly worthy of consultation. In it the palæontologist will find that the author, who has personally traced the Permian rocks over a vaster northern area than any other individual, enumerates the following fossils, never before described:—Diastopora labiata, Strophalosia tholus, Pleurotomaria atomus, and six species of Bivalved Entomostraca (mostly Kirkbyæ, according to Rupert Jones). Count Keyserling makes the important observation that, as these little bivalved Crustacea are very generally present throughout vast spaces of Russia in beds of Permian rock which contain no other fossil, it is essential to speak of these fossils as singularly characteristic of the formation. The Permian Entomostraca are carefully illustrated and described by Kirkby and Jones in the Trans. Tyneside Nat. Club for 1859.

Devonian strata, and which has very seldom been found in the Carboniferous rocks of England, has not yet been detected in Permian deposits. In unison, however, with the prevailing law of nature, which, in modifying beings at successive periods, often retained some features of the preceding types, the Pentamerus is represented in the Permian division by the curious terebratuloid shell named Camarophoria by Professor King, which offers in its internal arrangement an approach to the structure of the Pentamerus. One of the most frequent Permian shells, indeed, is Camarophoria Schlotheimi, von Buch, figured in the work on Russia, vol. ii. pl. 8. figs. 4, 5. This singular Brachiopod also disappeared at the close of the Permian era, and its place was occupied by genera, such as Terebratula or Rhynchonella, which exist even in the present day.

It is worthy of note that, of the eighteen Permian Brachiopods which are known in Britain, fifteen occur in the same strata in Germany; whilst among them are certain species, seven in number, which extend their range even to the north-eastern extremity of European Russia.

The following Table, published by the distinguished palæontologist Mr. T. Davidson, shows this distribution of the Permian Brachiopoda in Britain, Germany, and Russia*:—

LIST OF THE CHIEF BRITISH PERMIAN BRACHIOPODA.

In the Magnesian Limestone of Britain.	Occurring also in	
	Germany.	Russia.
1. Terebratula elongata, Schloth., var. sufflata	*	*
2. Spirifer alatus, Schloth.	*	*
3. Spirifer Clannyanus, King	*	
4. Spiriferina cristata, Schloth.	*	*
5. Spiriferina multiplicata, Sow.	*	
6. Athyris pectinifera, Sow.	*	*
7. Camarophoria Schlotheimi, von Buch	*	*
8. Camarophoria globulina, Phillips	*	
9. Camarophoria Humbletonensis, Howse	?	
10. Strephorhynchus pelargonatus, Schloth.	*	*
11. Productus horridus, Sow.	*	*
12. Productus latirostratus, Howse	*	
13. Strophalosia Goldfussi, Münster	*	
14. Strophalosia lamellosa, Geinitz, var. Morrisiana	*	
15. Crania Kirkbyi, Dav.		
16. Discina Koninckii, Geinitz	*	
17. Lingula Credneri, Geinitz	*	
18. Chonetes Hardrensis, Phillips.		

In the Lamellibranchiate Shells (the Dimyaria and Monomyaria), we note the same diminution of genera and species in reference to deposits of previous eras; and whilst not less than 288 species are known in the Carboniferous, about 73 only have been obtained in the Permian deposits. Myalina and Schizodus (King) are characteristic genera; Myalina Hausmanni and Schizodus Schlotheimi are abundant in the Upper Magnesian Limestone and Zechstein. S. obscurus and S. truncatus prevail in the lower strata of the series; and occur also in Russia. The genus Gervillia is also abundant, G. antiqua and G. keratophaga being very common in Western Europe. Another Aviculoid shell, now referred to Monotis (M. speluncaria), is wide in its range. Keyserling found it on the banks of the Pinega in the Province of Archangel; and it occurs in Germany,

* See Monograph of Permian Fossils: Palæontograph. Soc. 1858.

England, and in the United States. Arca striata and Clidophorus costatus are other characteristic species. Together with these are found species of Leda, Solemya, Edmondia, Myacites, Cardiomorpha, Astarte, Lima, and Pecten.

The Gasteropods also seem to have decreased in numbers during the formation of the Permian strata, and to have had great difficulty in accommodating themselves to new conditions*. In the Magnesian Limestone of Durham they are comparatively rare fossils, numbering 17 in a list of 58 species of Mollusca. In South Yorkshire, where individuals are numerous and species few, the Gasteropods number 9, and the other Mollusks 10. Turbo helicinus, prevailing largely there, and Turritella Altenburgensis and Pleurotomaria antrina are the most characteristic species of this class in England. Altogether there appear to be about 43 Permian Gasteropoda. Scarcely any of these have lived on from the Carboniferous to the Permian epoch†, though many belong to Carboniferous or, rather, Palæozoic genera, such as Pleurotomaria, Murchisonia, Straparollus, and Macrocheilus.

The Cephalopods, which under the forms of Goniatites, Nautilus, and Orthoceras were so numerous during the Carboniferous period that more than 160 species have been described from its strata, were greatly reduced previously to the commencement of the Permian era. The only species occurring in England is Nautilus Frieslebeni, Geinitz. Other species, belonging to the same genus and to Orthoceras and Cyrtoceras, have been described from the Zechstein of Germany and the Permian strata of the United States, making the list up to 10.

Three Pteropods have occurred, Conularia Hollebeni being the most important. Four species of Bellerophon occur in the Permian strata of Nebraska.

Trilobites are entirely wanting ‡. In the study of the Palæozoic Succession, we see that the disappearance of this race is regularly announced by a gradual diminution of its numbers during the preceding epochs. Appearing among the earliest forms of life, and having their maximum of development in the Silurian period, Trilobites decrease very sensibly in the Devonian strata, and in the Carboniferous deposits are reduced to some small species, of which Phillipsia and Griffithides are the last expiring forms. And here we are presented with one of those beautiful links in Natural History, of which the strata forming the earth's crust have afforded so many proofs; for, with the final extinction of this family, destined never more to reappear, its place is taken by allied Crustaceans, foreshadowing the Limulus, the earliest of which Limuloid Crustacea (Belinurus and Prestwichia) were created during the formation of the Coal-measures; and, represented perhaps in Permian rocks by the obscure Russian fossil known as the Limulus (?) oculatus of Kutorga, they were succeeded in the Secondary epoch by the Limulus itself; and that has survived all the numerous revolutions which have followed its creation, some of its species being coexistent with our own race §.

The preceding remarks refer more especially to the Permian fossils of Europe. Only of late years have we obtained information of the Permian species of America. It is interesting to find there that the same genera characterize the last of the Palæozoic systems as in Europe. In Kansas, Texas, and Nebraska, Permian rocks occur containing Productus, Camarophoria, Strophalosia, Streptorhynchus, Chonetes, Spirifer, Edmondia, Gervillia, Monotis, Schizodus, Murchisonia, Orthoceras, Bellerophon, and Fenestella. Not only are the genera the

* See also 'Russia-in-Europe,' vol. i. p. 209.

† See Mr. Kirkby's later remarks on the recurrence of Carboniferous Forms in Permian strata, Quart. Journ. Geol. Soc. vol. xvi. p. 416; and Ann.

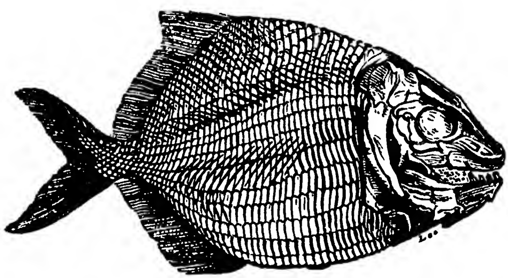
‡ Phillipsia perannulata has recently been described from the Permian strata of Kansas, but it is doubtful whether it may not really belong to the Carboniferous rocks.

same there as in the eastern hemisphere, but in several cases the species are identical with those found in the Magnesian Limestone and Zechstein. These fossils have been described by Messrs. Meek and Hayden *, Swallow and Hawn †, Shumard ‡, and very recently by Geinitz §.

On the whole, therefore, if only a very few species of Mollusks are common to the older rocks and the Permian, the latter still retains its connexion with the former through the genera Bellerophon, Edmondia, Athyris, Chonetes, Productus, Spirifer, and Strophalosia, its peculiar group of Corals, and of Polyzoa (Fenestellæ &c.). It is the constant diffusion of many individuals of such forms which induced my associates and myself to hold firm to the term 'Permian,' as marking the close of primeval life, and in separating it entirely from the Trias and other Secondary deposits, in common with which it contains no animal form.

The fossil Fishes of this era, of which more than forty species are known, all belong, like their precursors in more ancient times, to the division with heterocercal tails,—a distinction that becomes evanescent in the succeeding Secondary and Tertiary formations, and in our era is chiefly confined to the Lepidostean, Ray, Shark, and Sturgeon families, nearly all other species now living (about 8000 in number) having homocercal tails.

FOSSILS (86). PERMIAN FISH.



Platysomus striatus, Agassiz; from the Marl-slate, Durham.

Of true heterocercal Fishes of the Permian group, two figures only are here given, by which the reader will see that the back-bone is prolonged with a bend into the end of the upper lobe of the tail; whilst in the homocercal fishes, or those common in the younger rocks and in the present day, it terminates in the middle, between the equally balanced fins of the tail.

Palæoniscus, Pygopterus, Cœlacanthus, Pleuracanthus (Xenacanthus), Acanthodes, Acrolepis, and Platysomus, which are the prevailing genera of the Permian era (the same forms being found in England, Germany, and Russia), are also known in the Carboniferous epoch; but all the Permian species are distinct.

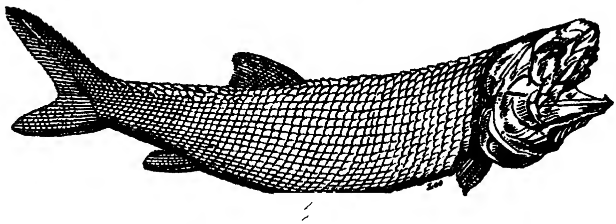
These Fishes are chiefly found in the Kupfer-Schiefer underlying the Zechstein in Germany; and in England they are met with in the equivalent deposit, the Marl-slate. Some small Palæonisci and a species of Acrolepis have lately been described from the upper beds of the Magnesian Limestone in Durham ‖.

Lastly, in enumerating the chief features of the Permian fauna, we have to

* Trans. Albany Instit. 1858.
† Trans. Acad. Sci. St. Louis, 1858.
‡ Trans. Acad. Sci. St. Louis, vol. i. p. 292, 1858.
§ Carbonformation und Dyas. Dresden, 1866.
‖ Kirkby, 'On some remains of Fish and Plants from the Upper Limestone, &c.,' Quart. Journ. Geol. Soc. vol. xx. p. 345, pl. 18.

recollect that, whilst few or no remains of true Lizards have been found in the subjacent formation (Carboniferous), the strata of this newer era contain the relics of Thecodont Saurians, which Owen refers to a higher order of Reptiles than any of the older fossils of this class, by showing that they had limbs as well organized as in the living Monitor*: the Proterosaurus, v. Meyer, and Rhopalodon, Fischer, were, according to him, Sauri which occasionally walked on dry land.

FOSSILS (87). PERMIAN FISH.



Palæoniscus Frieslebeni, Agass.; from the Kupfer-Schiefer of Mansfeld in Germany.

Struck with the fact of the Permian deposits containing Saurians, Conybeare† and Agassiz thought that the group ought to be placed at the base of the Secondary rocks, which mark the great era of Reptiles. But the discovery of Labyrinthodonts in the Carboniferous rocks of Europe and America has satisfied my colleagues and myself that this argument was insufficient, and that we were right in being guided by the general facies of the Mollusks and Plants, and in grouping the Permian (as Phillips had, indeed, previously grouped the Magnesian Limestone) with those antecedent deposits to which it is naturally attached by very many links.

The Dasyceps Bucklandi (Labyrinthodon, Lloyd), from the neighbourhood of Kenilworth, was found in red sandstones once considered to be of Triassic age, but since assigned to the Permian period‡.

Thus we learn that, in the oldest rocks (Upper Palæozoic) in which they first appear, the Reptiles are as wonderful and elaborate in structure as the primeval Fishes which accompanied them, or as the Corals, Crinoids, Shells, and Crustacea which preceded them during the Silurian or Lower Palæozoic epoch.

* See 'Russia-in-Europe,' vol. i. p. 213; and Professor Owen's description, p. 637, App. My friend the late Major Wangenheim von Qualen, to whom my associates and myself were much indebted for information respecting the structure of the Permian rocks of Orenburg, detected since our visit bones of another Reptile, which occurs, not, like the remains of the Rhopalodon (Fischer), in the sandstone and conglomerate, but in the limestone (Zechstein) of the formation. The preservation of the head of this animal has enabled M. Eichwald to assign to it the name of Zygosaurus Lucius, and to compare it with the Crocodile. On referring M. Eichwald's description (Bull. Soc. Imp. Nat. Moscou, 1852, No. 4) to Professor Owen, that celebrated comparative anatomist thus writes to me:—"The characters which M. Eichwald points out in his fossil as resembling those in the Crocodile also occur in the fossil skulls of the Labyrinthodont Reptiles; and the observation upon the number and comparatively small size of the teeth in the Permian Reptile would lead to a suspicion that it may really belong to the Labyrinthodont family. All doubt would be removed by an inspection of the occiput of M. Eichwald's fossil: if that part presented a single condyle for articulation with the neck-vertebræ, it would determine the accuracy of his view of its affinities; but if the occiput showed a pair of condyles, it would prove the fossil to be a Sauroid Batrachian."

† My lamented friend, the late eminent Dean of Asaph, equally distinguished for the broad geological views put forth in his 'Outlines of the Geology of England' and for his anatomical illustrations of Saurian Reptiles (see Trans. Geol. Soc. vol. v. p. 559; and 2nd ser. vol. i. pp. 103 & 381).

‡ See Ramsay on the Permian Breccia, Quart. Journ. Geol. Soc. Lond. vol. xi. p. 198; and Huxley's Appendix to Howell's Geology of the Warwickshire Coal-fields, &c., Mem. Geol. Surv. 1859.

In concluding this Chapter, it may, indeed, be reasserted* that the mass of the organic remains of the Permian group constitute a remnant only of the earlier animals whose various developments we have followed in the preceding pages. They exhibit the last of the successive changes which these creatures underwent before their final disappearance. The dwindling away and extinction of many of the types which were produced and multiplied during the anterior epochs already announce the end of the long Palæozoic period.

In ascending above the highest of the Permian deposits, the geologist takes, indeed, a sudden and final leave of nearly everything in nature to which the words Primary, Primeval, or Palæozoic have been or can be applied.

In short, the two greatest revolutions in the extinct organic world are those which separated the Palæozoic rocks from the Mesozoic or Secondary strata, and the latter from the Cænozoic or Tertiary and Modern deposits.

To the consideration of these two remarkable revolutions in the history of former races, I shall revert in the concluding Chapter.

* See 'Russia-in-Europe,' vol. i. p. 205.

CHAPTER XIV.

GENERAL VIEW OF THE SILURIAN, DEVONIAN, AND CARBONIFEROUS ROCKS OF SCANDINAVIA AND RUSSIA.

COMPLETING in the last Chapter a notice of the Palæozoic rocks, in ascending order, by a sketch of the Permian deposits, special references were made to Russia, whence the name 'Permian' was taken, and to Germany, where the different strata of the group had been so long studied. Let us now endeavour to delineate in broad outline the Continental equivalents of the Silurian, Devonian, and Carboniferous rocks of Britain.

Throughout large portions of Western Europe (that is, Germany, France, Spain, and Portugal) these Palæozoic deposits have been, in some tracts, so much metamorphosed and crystallized, in others so penetrated by igneous rocks, and even so dislocated, that, notwithstanding the researches of many good geologists and mineralogists, the task of reducing them to a normal order of succession is far from being completed. Deferring, therefore, such explanation of these complicated regions as may be practicable, let us first take a view of the succession of primeval life in Scandinavia and Russia-in-Europe, where, on the contrary, the series of the older fossil-bearing sediments is exhibited, over very wide areas, in clear and symmetrical order, and for the most part uninterrupted by the intrusion of igneous rocks *.

In Scandinavia and Lapland, ancient crystalline rocks occupying the chief mass of that territory, and consisting to a great extent of granite and gneiss, with many varieties of schistose and quartzose strata, often metalliferous, in

* The limits of this work do not permit any attempt to delineate the mineral composition of the Ural Mountains, except to indicate by the way how clearly they exhibit the metamorphism of the Palæozoic deposits of Russia-in-Europe. An acquaintance with many of their natural productions must be sought in the works of other authors, from the time of Pallas to the days of the great traveller Humboldt, who explored these regions accompanied by his friends Gustaf Rose and Ehrenberg, and extended the lights of science to the frontiers of China. Besides the 'Reise nach dem Ural, dem Altai,' &c., of those authors, the reader will find a great body of information in the 'Archiv für wissenschaftliche Kunde von Russland,' conducted by M. Adolf Ermann, the explorer of North-eastern Siberia and Kamtschatka. Among the authors who have written on the mineral structure of Siberia, Helmersen and Hoffmann also stand out conspicuously, as will be seen by those who consult their publications in the 'Annuaire des Mines de Russie.' The splendid work also of M. Pierre de Tchihatchef, on the Altai Mountains, and many others would have to be noticed; but as this volume is chiefly an outline of the nature and succession of the older sediments, I cannot here expatiate upon the labours of many of my cotemporaries.

In the work 'Russia and the Ural Mountains,' references are given to the authors, both anterior and cotemporary, who have illustrated the older sedimentary deposits and their fossils in the Russian Empire. Special allusion is there made to the first (and a very able) attempt at the construction of a geological map of Russia by the late Hon. W. Fox Strangways (Earl of Ilchester), and to his original sketch of the environs of St. Petersburg, in Trans. Geol. Soc. Lond. 1st ser. vol. v. p. 392. References are of course also made to the original work of Pander on the fossils of the same district, and to Eichwald's 'Système Silurien de l'Esthonie.' Since the publication of our work, my friends and self have been gratified by seeing it translated (1849) into the Russian language by Colonel Osersky, who has added some important data from his own observation and other sources, including corrections of our general geological map. Several communications of value on the geology and fossils of Russia, by Helmersen and others, are to be found in the Bulletin Soc. Imp. Naturalistes de Moscou, and other serial works; and M. Eichwald's 'Lethæa Rossica' forms, as far as it has been published, a useful compendium of Russian Palæontology.

which nothing organic has been discovered, are covered at intervals by true representatives of the Silurian rocks. I have little doubt that the oldest of these rocks, particularly in the central and northern parts of Norway, tracts which I did not visit, will be found to underlie all the formations of Cambrian and Silurian age, and therefore pertains to the Laurentian.

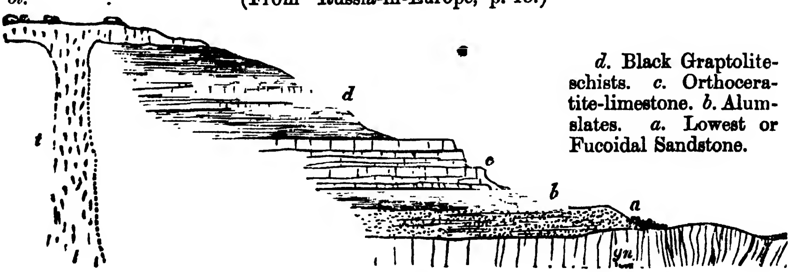
The lowest strata which have as yet afforded fossil animal remains are clearly the equivalents of the Lowest Silurian strata of the British Isles, Bohemia, and other countries.

In a recent tour in Norway, made to compare the effects of glaciation in that country with those known in Scotland *, Mr. Geikie ascertained from the communication of M. Tellef Dahl, who with M. Kjerulf is carrying out the Geological Survey of Norway, that there was also a great similarity in the general succession of the rocks of the two regions. Thus the Laurentian gneiss is represented by the widely spread crystalline rocks of Telemark, covered by red sandstone and conglomerates (probably Cambrian), which lie quite unconformably on the fundamental gneiss. Then follow schists with Dictyonema Norvegica, which may stand for the 'Primordial' Silurian zone. The last is surmounted by quartzites, and hornblendic and even gneissic schists, resembling the altered Lower Silurian of the Highlands of Scotland, and are manifestly of the same age as the unaltered Lower Silurian strata near Christiania. Other rocks, representing the Lower Old Red Sandstone of Scotland, surmount all the preceding series. It may be added also that, in Kjerulf and Dahl's new Geological Map of South Norway, a large area of green mica-schist, that was formerly thought to be azoic, is really composed of Silurian metamorphic rocks, in which obscure fossils, such as an Orthoceras and a Coral, have been detected. Also the extensive tract of sandstones, grits, and conglomerates, once regarded as Devonian, in the same region, are of Cambrian age, resting on Laurentian gneiss, and are much more extensive than the earlier maps depict them.

The first of the following diagrams represents the succession of Lower Silurian deposits from a base of crystalline gneiss and associated strata near Kinnekulle in Sweden †.

LOWER SILURIAN STRATA OF SWEDEN REPOSING ON GNEISS.

(From 'Russia-in-Europe,' p. 15.)



d. Black Graptolite-schists. *c.* Orthoceratite-limestone. *b.* Alum-slates. *a.* Lowest or Fucoidal Sandstone.

gn. Gneiss. *t.* Trap or eruptive greenstone. *bl.* Erratic blocks.

In other parts of Sweden, as near the Billingen Hills, the two lower groups of strata, *a*, *b*, of the above section are seen to rest upon granitic rocks without

* See Proc. Roy. Soc. Edin. vol. v. p. 532.

† A detailed geological map, including all the crystalline and metalliferous rocks of Sweden, has for some time been in preparation, but is as yet only partly published. This task was undertaken by MM. Forsells, Erdmann, Franzen, and Troilius, but abandoned. M. Erdmann, who has lately visited England, has now taken it up by authority, and will, I trust, complete this work.

any intervening crystalline schists. In such cases the lowest sandstone, which is used as a millstone, is simply a re-aggregated granite, the *arkose* of Brongniart; the materials having been derived from the subjacent rock.

OLDEST SILURIAN STRATA OF SWEDEN RESTING ON GRANITE.
(From 'Russia-in-Europe,' p. 16.)

b. Alum-schist. *a*. Fucoid-sandstone. *a'*. Arkose. *gr*. Granite.

Now, whether the subjacent rocks be composed of granite, granitic gneiss, or flinty slates, and quartzose or other crystalline masses, the fundamental strata in which any traces of former life can be detected are sandstones and schists, which stand in the place of the lower fossiliferous beds of Britain, and of that 'Primordial Zone' in Bohemia which will presently be noticed. The bottom beds contain Fucoids, or casts of Sea-weeds only; but the lowest band of schist is well characterized by its fossils in several parts of Sweden, and particularly at Andrarum, where it contains Trilobites of the genera Paradoxides, Olenus, Conocephalus, Agnostus, &c.

The limestones which next overlie (*c*, of the section at p. 346), and which abound in Orthidæ, large Orthocerata, Trilobites, and Cystideæ, are distinctly the equivalent of the British Llandeilo formation of schists, flags, and limestone &c. Above these, but connected with them, is a considerable mass of shale or schist, chiefly characterized by Graptolites; and this is covered by other limestones, which in Gothland are profusely charged with very many of the same species of Shells and Corals as are found in the limestones of Wenlock and Dudley. The whole of this series is capped, in the south of Gothland, by certain sandy strata, which are supposed to be meagre equivalents of the Ludlow rocks *.

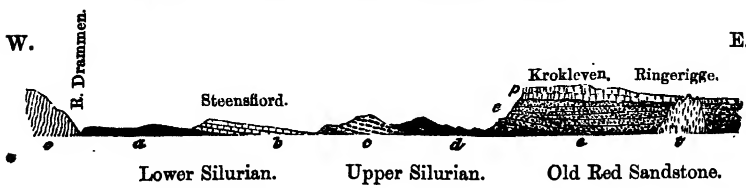
Whilst, however, the organic remains of the Silurian rocks of Sweden have been elaborately and ably described by various authors †, there is nowhere to be seen, in any one tract of that kingdom, the same concentrated succession of all these strata from their base upwards, or one natural section so clearly connecting the Lower and Upper Silurian, as is exhibited in Norway, and particularly in the territory of Christiania. There, as formerly described by myself, various strata, clearly divisible into 'Lower' and 'Upper' Silurian through their characteristic fossils, are regularly exhibited in a very small compass in the Steensfiord, between the River Drammen and the Krokleven, to the west of Christiania, where their uppermost member is conformably overlain by a great

* See details of this succession, by Murchison and de Verneuil, Quart. Journ. Geol. Soc. Lond. vol. iii. p. 1.

† See 'Palæontologia Suecica,' pt. 1. In this brief sketch, no justice can be done to the numerous works on the rocks and fossils of Sweden and Norway—countries which, from the time of Linnæus to the present day, have contributed so much to the progress of Natural History. In the memoirs of the veteran Nilsson of our time, in those of Wahlenberg and Gyllenberg of past years, and in the works of Lovén and Angelin, which have more recently appeared, the fossil organic remains have received much illustration in addition to the knowledge formerly communicated in the 'Lethæa Suecica' (1837) of Hisinger. G. Lindström's researches among the Gothland fossils are well known to palæontologists by his several memoirs on the Brachiopods, Operculated Corals, &c. The 'Gæa Norvegica' of Keilhau is well known for its description of the lithological character of the various Norwegian rocks. But the work which has completely worked out the precise relation of the component parts of the Silurian rocks of Norway is that of M. Kjerulf. It is from this publication that the data in the last edition of 'Siluria' were derived, which determined with so much exactness the similarity of the English and Norwegian Silurian rocks.

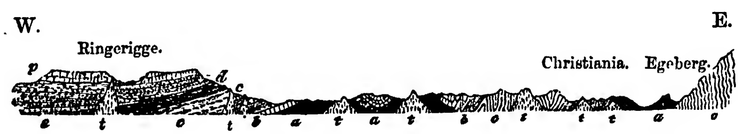
accumulation of Old Red Sandstone with conglomerate, as expressed in the two following diagrams*, prepared on the spot by myself in 1844:—

SUCCESSION IN NORWAY. (From 'Russia-in-Europe,' p. 10.)



o. Gneiss. *a.* Lower sandstones, schists, limestone, and flags. *b.* Limestone, with Pentameri. *c.* Coralline limestone (Wenlock). *d.* Calcareous flagstones (Ludlow). *e.* Old Red Sandstone. *p.* Rhombic porphyry. *t.* Other eruptive rocks.

The same strata prevail in the Bay of Christiania; but there they are at many points contorted and penetrated by syenites, greenstones, and hypersthenic rocks, whereby the Alum-schists below are here and there crystallized (*a*), and the limestone, *b*, converted into marble. The next section (a continuation to the east of the preceding diagram) explains their relations, and shows how the undulating and broken masses, regaining their order, fold over and dip under a great mass of Old Red Sandstone (*e*), the western extremity only of which is represented in the preceding diagram.



e. Old Red Sandstone. *d.* Calcareous flagstones. *c.* Coralline limestone and shale (Wenlock), beautifully exposed in many islands of the bay. *b.* Limestone, in parts a marble (as at Paradis-backen). *a.* Lower Silurian schists &c., in parts altered. *o.* Gneiss. *t.* Various eruptive rocks, whether syenites, greenstones, porphyries, or younger granites, which have been forced through the strata. *p.* The rhombic porphyry on the summit of the plateau.

Having now adverted to the sections of this tract which I made in 1844, when I first placed the older fossiliferous strata of Norway in parallelism with the Silurian and Devonian rocks of my own country, and showed that the thousands of feet of the Silurian strata of Britain are fully represented, as respects their fossils, by the hundreds of feet only which exist in Norway, it is most gratifying to find my inferences were eleven years afterwards proved to be true by the detailed labours of M. Theodor Kjerulf †.

Dividing the whole Silurian series of Norway into the three physical groups of Oslo, Oscarskal, and Malmö, M. Kjerulf has recognized fourteen distinct fossiliferous bands, as exhibited in the opposite sections.

In referring to the section, fig. 1, we see that the Alum-schists (2), with bituminous limestone, rest upon unfossiliferous and siliceous greywackè (1), the equivalent of the upper part of the Longmynd (Cambrian) of Britain. In No. 2,

* For the particulars of these phenomena, consult 'Russia-in-Europe,' vol. i. pp. 10 *et seq.*, and Quart. Journ. Geol. Soc. Lond. vol. i. p. 467 (Murchison 'On the Palæozoic Deposits of Scandinavia, &c., and their Relations to Azoic or more Recent Crystalline Rocks'), 1845.

† Das Christiania Silur-Becken, 1855. See also Quart. Journ. Geol. Soc. vol. xiv. pp. 36 &c.

Fig. 1.—GENERAL SECTION OF THE SILURIAN ROCKS IN NORWAY.

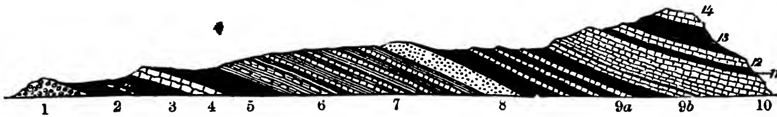


Fig. 2.—SECTION OF A PART OF LADEGAARDS-Ö.

N.N.W.
Beston Kilen.

S.S.E.

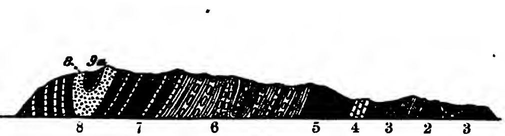


Fig. 3—SECTION FROM THE LOWER SILURIAN (CARADOC) ROCKS OF ORMÖ TO THE LOWER LUDLOW ROCKS OF MALMÖ.

W. Ormö. Malmö (130-150 feet). E.

Lingula-flags.
3. Lower Graptolite-schists.
2. Alum-schists.

1. Quartzite (Cambrian).

Caradoc Rocks.
8. Calcareous sandstone.
7. Calcareous and argillaceous flagstones.
6. Orthoceratite-limestone and Lower Encrinital schists.

Llandeilo Rocks.
5. Upper Graptolite-schists.
4. Lower Orthoceratite-limestone.

Upper Silurian.
14. Upper Malmö limestone.
13. Upper Graptolite-schists.
12. Lower Malmö or Upper Orthoceratite-limestone.

Llandovery Rocks.
11. Upper Encrinital schists.
10. Coral-limestone.
9b. Pentamerus-limestone.
9a. Lower argillaceous schists.

the lowest zone in which intelligible fossils have been detected in Scandinavia, there are found small Graptolites, the Graptopora * flabelliformis, several species of Lingula, including one like Lingulella Davisii, a horny shell nearly allied to Obolus Apollinis, Agnostus pisiformis, Olenus scarabæoides, Beck, Olenus latus, Beck (Eurycare latum, Angelin), Olenus alatus, Beck (Sphærophthalmus alatus, Angelin), Olenus gibbosus, Wahl., Asaphus grandis, and Trilobites pusillus, Sars.

This zone (2), being unquestionably the same as the 'Regiones A, B' of Angelin in Sweden †, is manifestly the northern equivalent of the 'Primordial Zone' of Barrande in Bohemia, and of the Lingula-schists of Britain, and, though only 150 feet thick, contains Graptopora flabelliformis mixed with Lingula, as in our own country, and with them Agnostus pisiformis and the Graptolite Didymograpsus geminus, as well as the common Silurian Brachiopod Orthis calligramma. The last three species occur also in the Llandeilo zone of the Silurian region of Britain. In other words, we thus see clearly that, in extending our survey, it is impracticable in general classification to separate the 'Zone Primordiale' of Barrande from the other Lower Silurian rocks.

The next mass of schists (3, 4, 5), with an intermediate limestone, bears a close analogy to its congener in Britain, by ushering in with it a profusion of species, and well represents the Llandeilo formation. Amongst its fossils are the Graptolites Diplograpsus pristis, D. folium, D. teretiusculus, Graptolithus sagittarius, and the Shells Orthis calligramma, O. elegantula (O. parva, de Vern.), O. flabellulum (?), Bellerophon bilobatus, B. acutus, Orthoceras duplex, O. annulatum, Lituites cornu-arietis, with Phacops conophthalmus (Asaphus Powisii, Sil. Syst.), and many other Trilobites of species peculiar to Sweden, but all belonging to the Lower Silurian genera, Asaphus, Ogygia, Trinucleus, Olenus, &c.

The group (6, 7) consisting of calcareous and argillaceous flags, intermediate Orthoceratite-limestone, and lower Encrinital schists, though intimately connected by many forms with the underlying divisions, is yet characterized by many other fossils, which enable us to refer it to the true Caradoc (or Bala) formation, as defined in the Fourth Chapter of this work.

These fossils are:—Orthis calligramma, O. testudinaria, O. pecten, Leptæna sericea, Lingula attenuata, Bellerophon bilobatus, B. acutus, Conularia quadrisulcata, and probably C. Sowerbyi, with other species; Orthoceras duplex, O. gigas, O. dimidiatum, O. distans, and O. annulatum,—the last three being Upper Silurian forms in Britain. The other fossils of Lower Silurian age are:—Lituites cornu-arietis, Trocholites anguiformis, Euomphalus and Turbo several species, including Euomphalus alatus, Hisinger?; with Echinosphærites aurantium, Tentaculites Anglicus (annulatus, Sil. Syst.), and the well-known Trilobites Asaphus expansus, Trinucleus concentricus (T. Caractaci, Sil. Syst., var.), T. seticornis, Ampyx nasutus, Ogygia, Calymene Blumenbachii (var. pulchella), and Phacops macroura, Sjogren, which closely resembles P. truncato-caudatus of the British Caradoc formation. The Corals are:—Favosites (Stenopora) fibrosa and its variety Lycoperdon, with species of Turbinolopsis (Petraia), &c.

The calcareous sandstone (No. 8 in the sections) would seem, from its organic remains, to constitute the commencement of a transition from the Lower to the Upper Silurian rocks, such as is seen in the Lower Llandovery rocks of

* The generic name proposed by Mr. Salter in 1857 (see p. 46) for this curious form, which seems to connect the Fenestellidæ with the Graptolites. It is, however, the Phyllograpsus, Angelin, MS., Report of Amer. Assoc. for 1857, Montreal.

† See M. Barrande's lucid memoir, 'Parallèle entre les Dépôts de Bohême et de Scandinavie,' 1856.

South Wales. Thus with Orthis testudinaria and O. zonata, Dalm., and Patella (?) antiquissima, His., occurs a characteristic Lower Llandovery species, Meristella angustifrons, M'Coy, and many large smooth Pentameri of species not yet named. Here are some associated fossils which are also commonly found in the Upper Silurian rocks of Britain. These are:—Strophomena depressa, Euomphalus sculptus, Phragmoceras? (Cyrtoceras) ventricosum, Encrinurus punctatus, Actinocrinus moniliformis, Favosites alveolaris, Heliolites megastoma, Halysites catenularius, Cyathophyllum turbinatum, &c.

In speaking of the characters of the fossils of this zone, it is to be observed that the characteristic Lower Silurian Trilobites have already disappeared *.

The argillaceous schists with calcareous flags (No. 9 *a*) obviously represent also a part of that intermediate group, connecting the Lower and Upper Silurian, to which I assigned the name of 'Llandovery rocks;' for in these beds certain species of Pentameri are first met with, whilst the overlying limestone (9 *b*) is, as in Britain, charged with Pentamerus oblongus: it forms in both countries a clear horizon.

The fossils are:—Fenestella asimilis, Alveolites repens, Cœnites intertextus, Ptilodictya scalpellum, Halysites catenularius, Orthis calligramma, O. elegantula, O. testudinaria, O. pecten, O. zonata, Dalm., O. lamellosa, Strophomena depressa, Leptæna transversalis, Orthis insularis, O. biforata (Spirifer lynx, Sp. dentatus, Atrypa crassicostis, &c.), O. biloba (Sp. sinuatus, von Buch), Cyrtia trapezoidalis, Trigonotreta compressa, Pentamerus galeatus, Stricklandinia lens, Atrypa reticularis, Linn., A. prunum, A. tumida, and A. aspera, Dalm., Euomphalus funatus, E. sculptus, Acroculia haliotis, Calymene Blumenbachii, Encrinurus punctatus, Ampyx, Acidaspis, and Trilobites (Proetus ?) ellipsifrons of Esmark, T. elegans, Sars, &c.

The band with Pentamerus oblongus is at once followed by another limestone (No. 10) highly charged with Corals and Crinoids, and evidently characterizing the mass of the Wenlock limestone. It is, however, important to remark that, with many Corals, and Euomphalus sculptus, E. carinatus, and even Orthoceras annulatum and O. ibex, we again meet with Pentamerus oblongus of the subjacent band, thus linking together, still better than in England, these beds with the inferior strata, and showing a higher vertical range of the above species of Pentamerus than is known in England, where it never rises into the Wenlock formation. The list of fossils includes Ptilodictya lanceolata, P. scalpellum, and the Corals Cyathophyllum turbinatum, Goldf., Ptychophyllum patellatum, several species of Heliolites, and several forms noticed in the underlying strata, with Sarcinula organum, a species of Lower Silurian age in Britain. The prevailing Encrinite is Actinocrinus moniliformis, Goldf.; whilst Cornulites serpularius is accompanied by the following shells—Rhynchonella borealis (Terebratula plicatella, Dalm.), Euomphalus carinatus, E. sculptus, and other spiral forms, Orthoceras ibex, O. annulatum, with Pentamerus conchidium and the other species above noted. The Encrinital schists (11) and Upper Orthoceratite-limestone (12), the Upper Graptolite-marls (13), and the Upper Malmö limestone (14), with the schists and marls of Overland, Opsahl, Noes, Krogsand, &c., represent other members of the Upper Silurian, as far as the lower and middle members of the Ludlow rocks inclusive,—the Upper Ludlow rock not being well represented by fossils.

Whilst the ordinary Wenlock Corals seem to pervade all the last-named

* Some of these Corals and Shells in Britain range from the Caradoc formation to the base of the Ludlow rocks.

rocks, their lower members, or the Encrinital schists and Orthoceras-limestone, characterized by large Orthocerata with central siphuncles, may, however, be supposed to represent the Lower Ludlow,—the more so, as they contain Gomphoceras pyriforme. In the overlying shales, Graptolites priodon (Ludensis) abounds; but it is to be noted that this zoophyte is associated with Retiolites Geinitzianus, Barr., and Cyathocrinus rugosus, both of Wenlock age, in Britain,—the former even pointing to the very base of the formation.

Even the upper limestones, schists, and shales, as seen at Malmö and the places above cited, are still charged with some Corals and Crinoids, known in England in the Wenlock formation only, including among the latter Eucalyptocrinus decorus and Crotalocrinus rugosus. On the other hand, here are also found some of the typical species of the Ludlow rocks, viz. Chonetes lata, Rhynchonella Wilsoni, Rh. navicula, Cyclonema corallii, Pterinea retroflexa, Orthoceras ibex, &c.

In my own rapid survey of the environs of Christiania, as formerly explained to the Geological Society, I could not, any more than M. Kjerulf, detect fossils indicative of the uppermost Ludlow rock, though I then pointed out a conformable passage upwards from the grey Upper Silurian rocks into an overlying red sandstone. In some parts of Sweden, however, and on another occasion, my coadjutor M. de Verneuil and myself detected organic remains in strata which must, we thought, represent the Upper Ludlow, and even a transition into the Devonian. Thus in Scania we found true Upper Ludlow fossils in red flaggy sandstones which Forchhammer had classed as Old Red Sandstone *.

Again, in proceeding from the northern and central parts of Gothland, which are occupied by the Wenlock limestone, we at length reached beds of a sandy and marly character, in which some of the species above mentioned, including Pterinea retroflexa, Chonetes lata, and Cyclonema corallii, were collocated with Rhynchonella nucula, Orthonota retusa, Murchisonia articulata, and Beyrichia tuberculata, all fossils of the Upper Ludlow rock.

The detailed sections of the Norwegian strata are most valuable in demonstrating, by comparison, that the Silurian rocks of Norway are, from their base upwards, the true equivalents of those in Britain, and also in showing that the Alum-schists, like the 'Primordial' Silurian strata, form the natural-history base of the Silurian system. The sections also demonstrate that, from this base to the uppermost beds, these zones (in all occupying less in the Christiania basin than 2000 feet in vertical dimensions) represent the whole of the vastly expanded British series, and constitute one conformable and natural system, whether viewed physically or zoologically †.

Subsequently to the issue of the excellent work the 'Silurian Basin of Christiania' ‡, M. Kjerulf and M. Tellef Dahl pointed out that the whole of the above-mentioned Silurian deposits repose upon quartzose rocks (to the north of Christiania) which in 1857 the authors referred to Cambrian age §. In a separate work they proved that the silver-ores of Kongsberg occur in crystalline rocks (whether gneissic, hornblendic slate, mica-schist, or quartz-rocks) which are older than the lowest Silurian ‖. Another and more elaborate description of the Silurian basin of Christiania by Kjerulf himself followed in 1865 ¶, illustrated by

* Quart. Journ. Geol. Soc. vol. iii. p. 34.

† Judging from a collection transmitted by M. Kjerulf, and examined by Mr. Salter, the specific identification with the British forms may for the most part be depended upon.

‡ Christiania Silur-Becken chemisch-geognostisch Untersucht (Christiania, 1855).

§ Ueber die Geologie des südlichen Norwegens (Christiania, 1857).

‖ Om Kongsbergs Erts District (Christiania, 1860).

¶ Veiviser (Christiania, 1865).

a detailed map and drawings of many fossils, showing that the lowest fossiliferous strata contained Graptolitidæ with the well-known Lower Silurian Brachiopods Orthis callactis, Atrypa lenticularis, Dalm., Lingulella Davisii, together with Olenus and other Trilobites. Lastly, in the same year, MM. Kjerulf and Tellef Dahll brought out a geological map of all Southern Norway, accompanied by many sections *. In this last work, as in the preceding publications, the varied geological features have been laid down upon the same topographical map on which the late Professor Eichwald delineated the structure of Norway. All geologists who make the comparison will therefore see at once what vast advances have been made in the last twenty-three years, or since I first applied (in 1844) the Silurian classification to the rocks of that kingdom.

The general ascending series, as worked out and as exhibited in the map, tables, and sections of Kjerulf and Tellef Dahll, is as follows:—

1. Fundamental rocks of gneiss, and quartzose, hornblendic and micaceous slates, with some bands of crystalline limestone. These may represent the Laurentian rocks of North America and the North-west of Scotland.

2. Talcose schists and other metamorphosed rocks, with dolomites. These the authors now refer to the so-called 'Taconic' rocks of North America; but as the latter have been ascertained to be nothing more than metamorphosed integral parts of the ordinary Lower Silurian, the use of this term is misplaced †. These masses seem, indeed, to occupy the very place of the 'Primordial' Silurian Zone of Britain and Bohemia; for in parts they contain the same Trilobites and well-known common Brachiopods of the ordinary Lower Silurian rocks, by which they are overlain conformably.

3. Great mass of the Lower Silurian rocks, overlain in many places by Upper Silurian, which, as before stated, is surmounted by Old Red Sandstone.

In addition to this description of all the older stratified rocks, MM. Kjerulf and Tellef Dahll have laid down upon their map the outlines of eight varieties of igneous rocks, from the oldest granites of the icy Dovre-Feld, through a succession of molten rocks of different ages, including gabbro and syenite, up to the porphyries and quartzose porphyries. They have also indicated by separate colours the chief events in the series of glacial changes, from the most ancient moraines of land-glaciers, through the succeeding operations of ice, whether in connexion with the deposition of gravel, sand, and sea-shells, or the transport of erratic blocks, followed by great alluvial accumulations. Such labours are worthy of all praise.

Besides the clear order of superposition of the various Silurian rocks and their identification by fossils, M. Kjerulf has further shown how different members of the series have been here and there metamorphosed into crystalline gneiss. The numerous points at which the sedimentary formations have been pierced by eruptive rocks long ago suggested to the late Professor Forchhammer and myself a sufficient explanation of such conversions ‡.

This subject has, indeed, been since worked out in some detail by Mr. David

* 'Geologische Karte,' Kjerulf and Tellef Dahll: Christiania, 1858–65.

† Not only Sir W. Logan and the Canadian Surveyors, but, as far as I know, all American geologists now admit that the 'Taconic' schists and slates of Emmons are simply the metamorphosed representatives of the Quebec (Lower Silurian) Group of those regions. Judging, however, from their fossils, I apprehend that in Norway the rocks which Kjerulf and T. Dahll have called 'Taconic' are simply a northern extension of the 'Primordial' Silurian rocks of Barrande, which in North Wales exhibit a great expansion as Lingula-flags. In Norway, indeed, they are demonstrated to be an integral part of the Silurian system by containing Graptolitopora (Dictyonema), together with Olenus and common Lower Silurian Brachiopods. According to my view, these beds, ranging into the central mountains of Norway, are proved by their fossils to be simply expansions of the much more diminutive Alum-slates of Sweden, Bornholm, and Norway.

‡ Quart. Journ. Geol. Soc. vol. i. pp. 470, 474, &c., and Russia-in-Europe, vol. i. p. 14, *note*.

Forbes, whose residence at Christiania enabled him to contribute satisfactory information, clearly demonstrating the conversion of sedimentary Silurian strata into crystalline rocks replete with simple minerals *.

To resume the history of succession. The 'Primordial' fauna of Scandinavia, which I long ago characterized as 'the earliest zone of [then] recognizable life,' consists, in its lowest stage, of Fucoids only. The next zone contains the Graptolites, Shells, and Trilobites before alluded to, some of which are identical with fossils of our Lingula-flags of Britain, or the 'Zone Primordiale' of Barrande. Its Trilobites have been elaborately described by Professor Angelin †, who has added much to our acquaintance with these fossils. Among the Crustacea of these beds ('Regiones A, B' of Angelin), we recognize in Sweden several of the genera which characterize some of the lowest of the fossiliferous beds of Britain. The most plentiful of these Crustaceans are Agnostus pisiformis and many species of Olenus, of which last-named genus some species also occur in the black schists of our Malvern Hills (p. 45).

Then the Swedish 'Regiones C and D' of Angelin are, as in Norway, nothing more, as respects their fossils, than masses of Lower Silurian rocks (Llandeilo and Caradoc) as described in England and Wales, and which reappear in great force in the Bay of Christiania, Norway. They are specially identified by the abundance of Trilobites of the same genera as those in our British strata of this age, viz. Asaphus, Ogygia, Remopleurides, Trinucleus, Illænus, Ampyx, &c. Many species of Trilobites and Mollusks of the two countries are identical, as shown by the preceding details.

Having examined these Lower Silurian rocks over various tracts of Sweden and Norway, I can assure geologists that, rich as they are in fossils (so rich that they have enabled M. Barrande, as will soon be seen, to parallel every one of their stages, from the lowest upwards, with the 'Primordial' and succeeding zones of Bohemia), the whole of the lower Silurian of Scandinavia never much exceeds in vertical thickness about 1200 feet! And yet this mass is as complete in the development of life as the 30,000 feet of strata of the same age in Britain, which have been so much expanded by intercalations of igneous matter! Nay, the general succession is essentially the same as in our islands; for the Lower Silurian of Sweden and Norway is conformably overlain by a zone charged with Pentamerus oblongus, and passes up into shales and limestones which completely represent the Upper Silurian, particularly the Wenlock formation.

And here, in respect to nomenclature, I may observe that the geologist who should seek to separate the Lower Silurian of Sweden and Norway from the Upper, and call the higher part only Silurian, would make a distinction which could not be followed out upon any map; for these

* Quart. Journ. Geol. Soc. vol. xi. pp. 166 &c. † Palæontologia Suecica, pt. 1, 1852.

two groups are there often exhibited, as in the preceding sections, in such frequent undulations as to constitute one united mass of very small thickness, all the strata of which have a community of aspect, and maintain a perfect parallelism to each other.

The identity which I formerly established * between the chief limestones of Gothland (together with certain isles in the Bay of Christiania) and those of Wenlock and Dudley was proved by the great number of the fossils common to Scandinavia and Britain, and is now well known to all geologists and collectors.

Silurian Rocks of Russia.—Following these ancient deposits into the Baltic Provinces of Russia, and beginning our examination of them in the environs of St. Petersburg, where their lowest beds are exposed, we find that the hard crystalline rocks of Scandinavia and of Finland have subsided beneath the sea-level, and that we can nowhere observe that junction, so clearly observed in Norway and Sweden, between the lowest Silurian rock and the masses which were formed before it.

Ranging from the banks of the River Neva at the Imperial metropolis to the cliffs west of Narva, the lowest visible strata are composed of bluish or greenish shale (the 'blue clay' of Russian geologists), though, in sinking the piles for the support of the new granite bridge at St. Petersburg, and in other subterranean works, courses of incoherent sand have also been met with in it. This clay, although as soft as that of Tertiary age in and around London, and so plastic as to be used even by sculptors for modelling, is clearly of the same age as some of the oldest strata described in Sweden and Norway, or as the much harder and more crystalline lowest Silurian slates of Wales; so entirely have these venerable Russian strata been exempted from the influence of change.

The lower clay or shale is followed upwards by sandy beds in parts sufficiently coherent, particularly when cemented by oxide of iron or a little calcareous matter, to form a sandstone, occasionally a calcareous grit, on which the Castle of Narva stands. On the banks of the Rivers Ishora, Tosna, and Siass, tributaries of the Neva, these sandy strata are interlaminated by thin courses of shale, approaching to impure fuller's earth, the sandier parts of which are intermixed with green grains, and occasionally contain small concretions. In these layers Pander found several of his microscopic Conodonts; but the organic bodies which specially characterize this band are Obolus Apollinis, Eichw. (the Ungulite of Pander), Orbicula (?) Buchii, and O. (?) reversa, de Vern., and some rarer shells termed Siphonotreta and Acrotreta. Of these, however, the little horny Brachiopod the Obolus or Ungulite is so much more abundant than any other fossil as to have induced Pander to give to the rock the name of 'Ungulite-grit.'

This Ungulite-grit is overlain by a course of dark-coloured schist, which contains Graptolites, and is often bituminous, particularly in Esthonia, where it has even been extracted for fuel.

It was in the green sands associated with the Ungulite-grit and bituminous shale, that the distinguished palæontologist, the late Dr. Pander, discovered those minute bodies (of the size of pins' heads and less) which he termed Co-

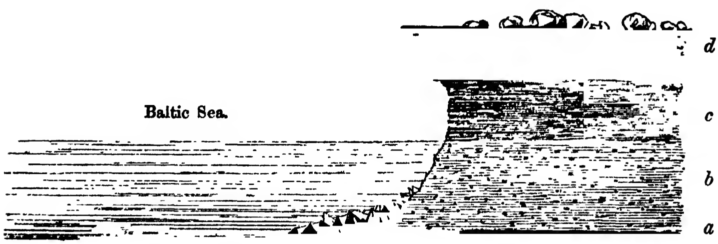
* Quart. Journ. Geol. Soc. vol. iii. pp. 18 &c.

nodonts, and which were referred by him to Fishes. If this suggestion had been borne out by inquiry, my broad generalization as to the first appearance of vertebrata, and to which I attach great importance, would have been set aside; but the able microscopists Carpenter, Quekett, and Harley, as well as Barrande and others, have rejected the idea of their being parts of Fishes, referring them to Crustacea and other low animals. Professor Owen, having favoured me with a similar opinion, declared that they present 'the most analogy with the spines, hooklets, or denticles of naked Mollusks and Annelides.' The detailed description of them by Professor Owen is given in the Appendix (E), and thus the question is completely set at rest.

A curious addition to our acquaintance with the minute fossils of the green sand of these Lower Silurian rocks of Russia was made by my eminent friend Dr. Ehrenberg, who discovered that many of the green grains consist of the siliceous casts of Foraminifera †.

The chief or Orthoceratite limestone (the Pleta), which follows, is characterized at its base by sandy calcareous beds containing a profusion of those dark-green grains which are here and there apparent in the subjacent strata, and which have been supposed to be the débris of ancient augitic rocks of Finland (see 'Russia-in-Europe,' p. 28*), but may, to some extent at least, have been derived from the silicated moulds of Foraminiferal shells. In lithological aspect, however, these lower calcareous beds usually so resemble the 'Craie chloritée' of the French, or the green varieties of the Upper Greensand of England, that, when mineral characters alone guided geological classification, they were even supposed by Alexander Brongniart to belong to the Cretaceous system. That misapprehension, however, was long ago removed by the works of Pander and Strangways. Separated by wayboards of greenish-grey or reddish shale, these green calcareous beds are surmounted by the earthy, grey, flat-bedded limestone which, occupying the hills of Czarskoe Celo and Duderhof south of St. Petersburg, ranges westward into Esthonia, and is the chief fossiliferous band of the Lower Silurian rocks. Conodonts have been found by Pander chiefly in the

LOWER SILURIAN ROCKS IN THE CLIFFS NEAR WAIWARA, GULF OF BOTHNIA.



a. Lower shale, obscured by fallen fragments of rock and ice-borne Scandinavian blocks. *b.* Ungulite-grit. *c.* Argillaceous schist, with Graptolites (Phyllograpsus). *d.* Orthoceratite-limestone (covered by granite-blocks which were transported from Sweden during the Glacial Period: 'Russia in Europe,' vol. i. pp. 34, 511 *et seq.*).

green sandy beds underlying this rock, although they have been also found by him and others in the overlying mass of the great Lower Silurian limestone, in

† See British Assoc. Report for 1854. In the 'Proceedings of the Berlin Academy' for June 1856, the reader will find an account of Ehrenberg's researches on the subject, some figures of these casts (which are considered by him to be new forms), and references to collateral observations by others.

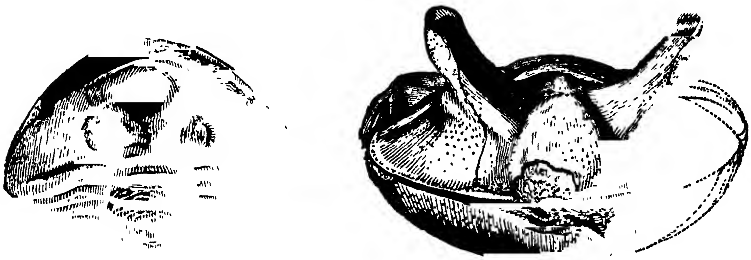
parts of the Upper Silurian and Devonian rocks, and even in the Carboniferous Limestone.

In the cliffs of the Gulf of Bothnia, the above-mentioned Lower Silurian limestone appears in relation to the underlying strata as in the preceding woodcut.

These lower limestones, constituting the chief members of the Lower Silurian of Russia, are filled, as in Scandinavia, with a profusion of Trilobites, Orthidæ, large Orthoceratites, Gasteropods, and Cystideæ, characteristic of this age. One only (and the most remarkable) of the Trilobites is here represented (Foss. 88), namely the singular variety 'cornutus' of the common Asaphus expansus of Wahlenberg.

FOSSILS (88). ASAPHUS EXPANSUS, AND ITS var. CORNUTUS, FROM THE LOWER SILURIAN LIMESTONE OF RUSSIA.

(From 'Russia and the Ural Mountains,' vol. i. p. 37.)



Among the other characteristic fossils may be cited Amphion Fischeri, Eichw., Illænus crassicauda, Dalm., Ampyx nasutus, Dalm., Cybele verrucosa Dalm., Orthis calligramma (Pl. V. f. 7, 8, 9), O. biforata, Schloth., Orthoceras duplex, Wahl., and many Cystideans, of which Echinosphærites aurantium is the type.

Here, laying before the reader a reduced sketch of the very characteristic and

FOSSILS (89). ORTHOCERAS DUPLEX, WAHLENBERG.

A characteristic Russian and Scandinavian fossil.

large Orthoceras of the Lower Silurian rocks of Scandinavia and Russia (Foss. 89), we must refer to the works of Pander and Eichwald *, and to that of myself and colleagues, for a full description of these fossils.

In proceeding westwards from the Government of St. Petersburg into Es-

* In citing the name of Eichwald, I must express my regret that, after demonstrating the identity of the strata forming the seaboard of the Baltic provinces of Russia with the rocks of Britain under the term 'Silurian' ('Silurische System in Esthland,' 1840), he should have gone back to the obsolete term 'Grauwacké.' The use of this word as respects the Russo-Baltic rocks of this date is wholly inapplicable, since no one band of these presents the lithological character of German 'Grauwacké.' (See 'Der Grauwackenschichten von Liev- und Esthland,' Bull. de la Soc. Imp. de Moscou, 1854, p. 3). See also his later memoir (Bull. Soc. Moscou, 1856-57) for copious lists of all the known Palæozoic Fossils of Russia. The distinctions of Lower and Upper Silurian, Devonian, &c., are all omitted, and 'Grauwacké' is again forced into nomenclature!

thonia, the calcareous flagstones (Pleta) are underlain by a bituminous and inflammable shale (see p. 355), formerly described by General Helmersen*. Occurring at Tolks and Pungern, this shale is very rich in well-preserved fossils, including many Trilobites of the genera Ampyx and Trinucleus, as well as the long-known typical British shell, Leptæna sericea of Sowerby.

Then follows a fine-grained limestone, which, forming the northern half of the Isle of Dago, is, according to Professor Schmidt, who has worked out the details of this region, the upper limit of the Lower Silurian rocks of Russia. The fossils contained in this band are indeed all truly of the age of the Caradoc beds of Britain, including the Calymene brevicapitata, Encrinurus multisegmentatus, Leptæna sericea, Orthis Actoniæ, O. testudinaria, with Murchisonia bicincta, Hall, and various types known in rocks of this age in America. This limestone, which contains also several characteristic fossils of the inferior 'Pleta,' including Orthis lynx and Chætetes Petropolitana, terminates upwards in beds laden with Corals of the genera Halysites, Heliolites, Caninia, Sarcinula, &c.

Upper Silurian.—In the large work on Russia, Upper Silurian deposits, like those of Gothland, were only spoken of by myself and companions as existing in the Isles of Oesel and Dago. With the limited time at our command, and in a flat country much obscured by Drift, we did not pretend to draw any defined line between the Lower and Upper Silurian. Seeing, indeed, that Pentamerus oblongus occurred in a calcareous band ranging above the Lower Silurian cliffs of Esthonia, it was natural on my part to refer that stratum, as I had done in England, rather to the top of the lower than to the base of the upper group.

Subsequent researches, however, and the preponderance of certain Wenlock fossils, have rightly led the Russian geologists to class this Pentamerus-band with the Upper Silurian †. In truth, the whole series in Russia, as in Scandinavia, is of such very small vertical dimensions (not, perhaps, a fortieth part of the magnitude of the grand British deposits) that, in a region where all these strata are conformable, and where, to use the expression of my associate Key-

* In addition to various able memoirs which he has written on the crystalline and palæozoic rocks of Russia, to the geological maps which he has prepared, and to his late works on the Devonian rocks, my associate in the Imperial Academy of St. Petersburg, General Helmersen, has published an account of the nature and position of this shale. It is certainly one of the oldest deposits which have combustible properties; but the petroleum of the Longmynd and of Pitchford (see p. 27) is of far older date, and in rocks wherein no trace of land plants has been detected. It is probable that most of the bituminous and anthracitic beds of these early periods owe their carbon and hydrogen chiefly to decomposed marine vegetables. (See Helmersen, 'Sur le Schiste argileux-bitumineux d'Esthonie,' Journal des Mines de Russie, 1838, p. 97.)

† M. Ozersky, who translated the work by myself and associates, 'Russia-in-Europe,' into the national language, was the first person to call attention to the succession of those upper calcareous Silurian strata, though, when he wrote, the fossil distinctions now worked out were unknown. Afterwards, in a short article (Ermann's Archiv für Russland, 1848, p. 236), Dr. Pander noticed the superposition of a rock charged with Pentamerus oblongus and many Corals to the well-known lower limestone of St. Petersburg. Another important contribution to clear up the subdivisions of the Russo-Baltic Silurians was made by Professor Kutorga, in a map of the Government of St. Petersburg, the result of ten years of labour (Compte Rendu de la Société Minéralogique de St.-Pétersbourg, 27 Janvier, 1852). Representing a continuous band of Upper Silurian between the Devonian and the Lower Silurian to the west of St. Petersburg (a tract which I never examined), he admits that to the south and east of the metropolis the succession is what my friends and myself represented it to be, viz. Devonian rocks at once resting on Lower Silurian, with one or two minute traces only of the lower band of the Upper Silurian, or the limestone with Pentamerus oblongus. Wherever, as in Russia and America, that fossil, or its representative form, appears for the first time, in ascending order, in strata otherwise charged with Wenlock fossils, the geologist has a perfect right to class the rock as Upper Silurian. Kutorga had previously shown that the Pentamerus-zone of Esthonia is surmounted, in the Islands of Oesel, Dago, and Möen, by still higher Silurian strata. These islands seem, in fact, to be equivalents of the southern end of Gothland (Hoburg), where I have described certain strata which represent the Ludlow rocks (Quart. Journ. Geol. Soc. Lond. vol. iii. pp. 1 &c.). In another work, 'Uebersicht des Silur-Schichten-Systems Lievlands und Esthlands,' 1852, M. Schrenk, the well-known explorer of the botany and mineral constitution of the North Ural Mountains, has, in conjunction with Professor Schmidt, extended considerably the range of the Upper Silurian; but the work of the last-mentioned author is that which, in conjunction with the great palæontological labours of Pander, has recently thrown the clearest light on the subject.

serling, all the strata (about 1500 feet thick) 'are but leaves in one united calcareous volume,' no distinctions can be drawn except by close examination of the organic remains.

The chief mineral masses of these overlying rocks are fine-grained limestones (passing in some beds almost into marble, and thus presenting a contrast to the incoherent and earthy Lower Silurian limestones of St. Petersburg), and magnesian beds (dolomite) occasionally somewhat crystalline and cavernous, here and there charged with white siliceous concretions. In other parts the strata are friable, marly, and of grey and yellow colours.

Rocks having the same mineral aspect, and containing the same fossils, appear, as I am informed by Keyserling, along the edge of the Timan Hills, in the distant region of the Petschora, at the mouth of the River Gatchina, and near the shore of the Icy Sea. It is further to be remarked that neither there nor in Esthonia (that is, in tracts 1000 miles distant from each other) has there been detected the slightest unconformity between the Lower and Upper Silurian rocks.

The task of working out the organic remains as respects Esthonia and the adjacent Islands of Wörmes, Dago, Oesel, &c. has fortunately been accomplished since the first edition of this work was published, by Professor Schmidt of Dörpat, whose views, as communicated to me by my associate Keyserling, have been published *. The coralline limestone forming the summit of the Lower Silurian series graduates in the same cliffs into a more marly limestone with Pentamerus linguifer, Strophomena pecten, and other fossils. The upper portion of the band is everywhere characterized by a profusion of Pentamerus borealis, another species (probably Pentamerus oblongus) being partially distributed; whilst the associated fossils are Calymene Blumenbachii, Encrinurus punctatus, Leptæna depressa, Atrypa reticularis, Leperditia Balthica, and L. marginata, with many Corals. Next follows a bluish-grey marlstone, in part a hard subcrystalline dolomite, whose chief fossils would seem to refer the rock to the Wenlock age, such as Lichas Gotlandicus, Orthoceras annulatum, Orthis elegantula, Leptæna transversalis, &c. This zone also contains many other Upper Silurian species.

The uppermost Silurian rock (as developed in the Isles of Oesel, Dago, and Möen) is a crystalline limestone, rarely dolomitic, the beds of which alternate with marly shale. This deposit contains many Mollusks found also in the Ludlow rock, such as Pterinea reticulata, Grammysia cingulata, Orthoceras bullatum, Murchisonia cingulata, Platychisma helicites, Rhynchonella Wilsoni, and Orthis orbicularis, together with Eurypterus remipes? (or E. tetragonophthalmus)—a representative of the group of Crustaceans which so much abound in the Ludlow rocks. Again, the resemblance of the Russian to the British deposit is marked by the first appearance of Fishes in the ascending order of deposits. Of the genus Cephalaspis, which in England first appears in this zone, the C. verrucosus of Pander (Thyestes, Eichw.), and C. Schrenkii, Pander, occur in the Isle of Oesel, together with Onchus Murchisoni, which is found also near Ludlow (see p. 138, and Pl. XXXV. f. 13, 14) †. These Uppermost Silurian

* Quart. Journ. Geol. Soc. vol. xiv. p. 43.

† In addition to the Cephalaspides (of several species), Professor Pander describes the following genera of Upper Silurian Fishes, mostly Ganoids, viz. Rytidolepis, Schidiosteus, Coccopeltus, Cyphomalepis, Trachylepis, Stigmalepis, Dasylepis, Lopholepis, Dictyolepis, Oniscolepis, Phlebolepis, Melittomalepis, Tolylepis, Lophosteus, Pterichthys, Cœlolepis, Pachylepis, Nostolepis. The Ichthyodorulites are Rhabdacanthus, Prionacanthus, Onchus.—The teeth are named Aulacodus (Sphagodus, Eichwald), Strosiphorus, Odontodus, Gomphodus, Coscinodus, Monopleurodus. If, by further comparison, several of these genera should disappear, the researches of Dr. Pander will still have made a very considerable addition to Upper Silurian Ichthyology. It remains, however, to be determined to what extent some of these uppermost beds in Oesel may not represent the base of the Devonian rocks.

grey beds of the Baltic Islands are manifestly the equivalents of the Upper Ludlow rock of Shropshire, on account of many of their invertebrated organic remains.

The work by Fr. Schmidt, 'Die Silurische Formation von Esthland, Nord-Livland, und Oesel' (Dörpat, 1858), completely sustains the views expressed in my previous edition. Little justice, however, is done to M. Schmidt's valuable details in this volume; and the reader who does not consult the original is referred to my memoir in the Quarterly Journal of the Geological Society, vol. xiv. p. 43, 'The Silurian Rocks and Fossils of Norway and the Baltic Provinces of Russia,' in which M. Schmidt's researches are fully treated of.

In his examination of Gothland, M. Schmidt has ascertained that the sketch which I gave in 1847, respecting the British equivalents of that exclusively Upper Silurian Island, is correct. In proceeding from the Wenlock Shale and Limestone on the north, M. de Verneuil and myself reached younger strata on the south, the highest of which represented the Upper Ludlow Rock. This view, though at first opposed by Helmersen, has been supported by Schmidt, who, among other arguments, has shown that the strata at the south end of Gothland contain the same species of Eurypterus (E. remipes?) as the uppermost beds of the opposite Russian Isle of Oesel, which contain numerous Ludlow-rock fossils.

M. Schmidt has given a detailed list of all the known Silurian fossils of the Russo-Baltic Provinces. Among about 425 species enumerated, the Corals, Graptolites, &c. amount to nearly 80 species; the Crinoidea, Cystideæ, &c. to 13; Cornulites, Tentaculites, and other Annelides to 5; the Polyzoa to 16; the Brachiopoda to nearly 100; the Acephala, Pteropoda, Heteropoda, and Gasteropoda to 69; the Cephalopoda to 39; the Crustaceans, including Beyrichia &c., to 67; and the Fishes (all of which, as in England, are in the Uppermost Silurian zone) amount to 40 species.

No one has laboured more successfully than my old colleague General Helmersen in elaborating the true structure of Russia. Since I quitted that country he has thrown light on many parts which my associates and self had not time to explore, and has published a map containing some important additions to that which we produced in the work 'Russia and the Ural Mountains.' He has also recently transmitted to me the following information:—

On the River Dniester, where my associates and self had inserted Silurian rocks upon our Map, M. Malemsey, a young student of the University of Kief, has discovered in limestone, shale, and sandstone, at Kamenetz, Kitaigorod, and other places in Podolia, a great number of fossils, which he has referred respectively to the formations of Llandeilo, Caradoc, Wenlock, and Ludlow.

Not attempting to assign to each fossil its exact place in the British Silurian series, I simply give M. Malemsey's list of the fossils which, as he supposes, represent the English formations, classing them as Lower and Upper Silurian specimens, and affixing to each a letter, as L. for Lower Silurian, U. for the Upper division, L. U. for those which occur in both deposits, and D. for Devonian:—

Amorphozoa.—Stromatopora polymorpha (U. and D.).
Cœlenterata (Zoophyta).—Acervularia ananas, Linn. (luxurians, Eichw.) (U.); Chætetes Fletcheri, M.-Edwards (U.); Cœnites intertextus, Eichw. (U.); Cyathophyllum articulatum, Wahl. (L. U.); C. ceratites, Goldf. (D.); C. flexuosum, Linn. (U.); C. quadrigeminum, Goldf. (D.); C. vermiculare, His. (articulatum, Wahl.) (L. U.); Favosites Gotlandica, Linn. (L. U.); Fistulipora decipiens, M'Coy (U.); F. cribrosa, M'Coy (U.); Halysites catenularius, Linn. (L. U.); Heliolites interstinctus, Linn. (L. U.); H. Mur-

chisoni, M.-Edw. (U.); Omphyma turbinatum, Linn. (L. U.); Stenopora (Favosites) fibrosa, M'Coy (L. U.); Syringopora bifurcata, Lonsd. (U.); S. fascicularis, Linn. (U.).

Echinodermata.—Actinocrinus nodulosus (D.); Crotalocrinus rugosus, Miller (U.); Poteriocrinus (Rhodocrinus) quinquangularis, Miller (L.); P. verus, Miller (D.).

Annelida.—Spirorbis.

Crustacea: *Trilobita.*—Calymene Blumenbachii, Brong. (L. U.); C. Baylei, Barr. (U.); Cheirurus insignis, Beyr. (U.); Dalmania (Phacops) caudata, Brün. (L. U.), Encrinurus punctatus, Brün. (L. U.); Bumastus Barriensis, Murch. (U.); Illænus Bouchardi, Barr. (U.); Proetus concinnus, Dalm. (U.); Sphærexochus mirus, Beyr. (U.). *Phyllopoda.*—Eurypterus tetragonophthalmus, Fischer (D.); Leperditia Balthica, His. (U.); L. phaseolus, His. (U.).

Polyzoa.—Ceriopora affinis, Goldf. (U.); C. granulosa, Goldf. (U.).

Again, in the eastern portion of the Government of St. Petersburg, M. Bock has observed that beyond the River Siass the upper beds consist of dolomitic limestone charged with Orthoceras duplex and O. regulare, lying upon a limestone with Orthoceras vaginatum. He infers that this band is of the same age as the rock between Narva and Revel, which alternates with the bituminous shale described by Helmersen in 1838. M. Bock believes that the limestone of the tracts east of St. Petersburg underwent a slight elevation soon after its formation, and was thus raised above the sea in which the Upper Silurian deposits of Oesel and Esthonia were accumulated.

Devonian Rocks of Russia.—Deposits of this age are so very widely spread out in Russia as to extend over a region more spacious than the British Isles. This great extension is not, however, due to the thickness of the beds, but to their very slight inclination, and to their having been rarely disturbed. Though subjected to broad and very slight bends only, they occupy the chief part of the Valdai Hills, and rise into a broad dome near Orel, thus constituting the highest eminences of a comparatively low region.

In addition to many Shells, some of them peculiar to the region, but others well known in strata of the same age in the limestones of Devonshire, in the Eifel, and some portions of the Devonian rocks of the Rhine and the Boulonnais, fossil Fishes occur in numerous localities, and strikingly characterize this deposit in Russia. Many of them, brought to England by myself, were shown by Agassiz to be identical with species of the Scottish Old Red Sandstone; whilst, from a microscopic examination of their teeth, Owen proved that some belong to Dendrodus*, a genus of Sauroid Fishes equally characteristic of the North-British formation. Cephalaspis Lyellii and the Pteraspides, which, with the associated large Crustaceans (Pterygoti), characterize the lowest zone of Old Red Sandstone in England and Scotland, are, as before said, unknown in Russia —a zoological datum which is in perfect harmony with the physical break usually observed, whereby this band is omitted and the Fishes of the middle and upper portion of the Old Red series of Scotland lie in strata which repose transgressively on various members of the Silurian rocks. It may, however, be suggested that the uppermost Silurian beds in the Isle of Oesel, with Cephalaspis verrucosus, exhibit a transition into the Devonian system.

When the first edition of this work was published, the existence in Russia of Coccosteus, so characteristic of the central zone in the north of Scotland, was unknown; but since then, thanks to the labours of the late Dr. Pander, the comparison has been rendered still more striking, not only by the addition of that

* 'Russia-in-Europe,' vol. i. p. 635.

remarkable form, but also of other well-known genera of the Caithness Flags—Osteolepis, Diplopterus, and Dipterus. The other Scottish forms, and even species, found by myself and companions, were, indeed, long ago identified by Agassiz and Owen as having their exact representatives in Russia. Such are the great Asterolepis (Chelonichthys) Asmusii, Ag., and the smaller species A. minor, Ag., with Glyptosteus favosus, Ag., Bothriolepis ornata, Eichw. (Glyptosteus reticulatus, Ag.), Holoptychius nobilissimus, Ag., Dendrodus strigatus, Owen, D. biporcatus, Owen, Cricodus incurvus, Ag. (Dendrodus, Owen), Pterichthys major, Ag., &c. *,—all belonging to the central portion of the deposit in Scotland † (see also p. 262).

When my colleagues and myself explored Russia, the connexion between the character of the fossils and the nature of the matrix in which they are imbedded was more pointedly brought before us in our range over that vast Empire than in any other region with which we were acquainted. In Courland, Livonia, and the Baltic Governments, as well as in the great central dome-like region of Orel, to which the formation extends, and where it has since been examined and ably described by General Helmersen, finely laminated limestones alternate with, and are subordinate to, great masses of sand, marl, and flagstone; and whilst in the calcareous courses Mollusks prevail, mixed with remains of Fishes, the latter are found most generally in sandy and marly beds. In tracing these rocks from the Baltic Provinces to the White Sea and Archangel, the limestones thin out, and the group is there represented only by sands and marls.

Accordingly we find that where the Russian rocks have the sandy character of the Old Red Sandstone which in Scotland and a large part of England represents the Devonian group in the British Isles, they are exclusively tenanted by Fishes,—a remarkable proof of the accordance between the lithological character and organic contents of rocks of the same age in distant countries.

Another and not less remarkable fact brought out by the survey of Russia is that the species of fossil Fishes well known in the middle and upper portions of the Old Red of Scotland, and which in large tracts of Russia lie alone in sandstone, are in many other places found intermixed in the same bed with those Shells that characterize the group in its slaty and calcareous form in Devonshire, the Rhenish country, and the Boulonnais. This phenomenon, first brought to light in the work on Russia by myself and colleagues, demonstrates more than any other the identity of deposits of this age, so different in lithological aspect, in Devonshire on the one hand, and in central England and Scotland on the other. The fact of this intermixture completely puts an end to all dispute respecting the exact correlation of the chief masses of the Old Red Sandstone of Scotland with the calcareous deposits of Devonshire, the Eifel, and the Rhenish Provinces. As this circumstance had been slightingly spoken of, I wrote to my colleague, Helmersen, to enable me to reassert the fact on his own knowledge, and he assured me that this intermixture of Fishes and Mollusks is visible in numerous parts of Russia, and that any person who may be sceptical has only to visit the Museum of the Imperial School of Mines to see

* 'Russia-in-Europe,' vol. i. p. 40, and fig. p. 636.

† The great work of Pander is a singularly valuable contribution to Palichthyology. The author adopts M'Coy's term of 'Placoderms' to denote a family composed of the genera Asterolepis, Eichwald, Coccosteus, Ag., Homosteus and Heterosteus of Asmus, and Chelyophorus, Ag. The Asterolepis, however, is not the Asterolepis of Hugh Miller. For the latter, Asmus's name Homosteus has the priority, according to Pander; while the Pterichthys of Agassiz is that which was first termed Asterolepis by Eichwald. (See, however, Sir P. Egerton's remarks on the subject in the Quart. Journ. Geol. Soc. vol. xvi. p. 122.)

M. Pander had evidently studied a great number of specimens of Asterolepis (Pterichthys) and Coccosteus with extreme care. He gives restorations of each, and figures of all their separate parts, which are of very great value to the palæontologist: while his laborious attempt to unravel the complexities of the synonymy of these Fishes is worthy of all praise.

in the same hand-specimens frequent examples of typical Devonian Mollusca together with Old Red Ichthyolites like those of Scotland *.

A similar intermixture has indeed been since recognized, to some extent, in the Devonian rocks of South England, the Eifel, and the Harz, and also in North America.

The progress of research had enabled M. Kutorga to divide the Devonian rocks of a part of Russia into three stages, in the ascending order—of clay and marl with Lingula bicarinata, compact sandstone with many Ichthyolites, and argillaceous limestone with many Brachiopods. M. Pander, in the notice previously referred to, has even shown that the highest of these beds is covered by other sandy strata, in which fossil Fishes of the Devonian epoch equally abound.

This author also distinguishes three stages in the Devonian rocks of Russia. The lowest consists of sandstones and shale, with those Ichthyolites which abound in the north of Livonia and the environs of Dörpat and Tellin: these are the Fishes which Asmus made known, and which Pander described in his First Fasciculus as Devonian Placoderms. In these beds Shells are rare; but the Lingula does occur, and its presence alone clearly shows that the associated Fishes were also inhabitants of the sea. These strata contain the same Fishes as the Caithness beds of the North of Scotland. The next stage, consisting of limestones, both dolomitic and simple, and of shales, is laden with marine Mollusca, which are mixed up in the same beds with various Ichthyolites, and extend over wide spaces. In this zone, as General Helmersen informs me, Productus productoides, Terebratula Livonica, Spirifer Archiaci, Sp. Anosoffi, and many other Shells, with Corals and Encrinites, are often commingled with remains of Holoptychius nobilissimus, and numerous bones and plates of other Fishes which Pander has described. This is manifestly one of the stages of the Old Red Sandstone of Scotland, the Holoptychius and other Fish-remains of which are thus proved to be of marine origin.

The third and highest stage, consisting of reddish sands, occasionally with green marls, seems to be simply an upward continuation of the band below it, and contains also some of the same Holoptychius with other Fish-remains.

In the more southern tracts near Voroneje †, it was shown, by myself and associates (and the phenomenon is now known to prevail in many other tracts), that many species of marine Brachiopods were commingled with Fishes in one and the same marly stratum. It follows, therefore, that the minute distinctions, lithological and organic, traceable in one district are not applicable to another, and that the limestones are mere local deposits in a great arenaceous and marly series of strata; whilst, on the whole, the identification of the group with its equivalents in other parts of the world has been established in the clearest manner by means of the fossil contents.

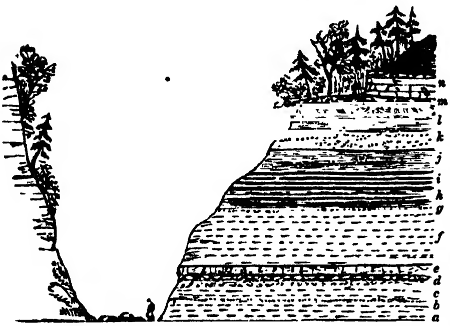
Reposing, as a whole, on the Uppermost Silurian in Esthonia, and on Lower Silurian in the Government of St. Petersburg, the upper members of these Devonian strata are in numberless places overlain conformably by, and pass up into, Carboniferous Limestone. In some tracts the strata consist of flag-like shelly limestones and marls, in others of sandstones both soft and hard, which range over extensive northern districts to the banks of the Lake of Onega and the shores of the White Sea.

* I can also cite with satisfaction another confirmation of my views, as conveyed in a letter I received from so high an authority as Pander, who wrote thus:—"The Devonian rocks, which are so clearly described in your work that one could almost find them in the dark, have attracted my particular attention on account of their Fishes; for by these remains, together with the characteristic Brachiopoda and Acephala, the agreement of the rocks of this system in Russia and Britain is shown in the clearest way."—April 1858.

† 'Russia-in-Europe,' p. 60.

In certain parts, as in the Valdai Hills, the upper beds (represented in the following woodcut) are red and green marls, containing several of the above-named fossil Fishes of the Old Red Sandstone of Scotland, the whole mass being covered by Carboniferous Limestone with its usual fossils, including many Producti.

RAVINE OF THE BELAIA IN THE VALDAI HILLS.
(From 'Russia-in-Europe,' p. 46.)



The lower beds, *a, b, c, d, e, f,* consist of various sands and marls, in which Ichthyolites are disseminated; but the bed *d* is a complete congeries of Fish-bones, surmounted by a copious mass of red, white, and green marls. Then follow bituminous schists, *g, h, i,* with courses of bad coal, constituting the bottom beds of the Carboniferous deposits; and after other alternations of sands and marls, *k, l,* they are followed by the Carboniferous Limestone, *m, n,* with many characteristic fossils, including even species which are well known in Britain, such as Productus hemisphæricus, P. punctatus, and P. semireticulatus.

In the distant region of the Petschora, Count Keyserling obtained satisfactory evidence that certain beds charged with Goniatites are inferior to all the other Devonian strata of Russia; whilst, as we shall presently see, the chief Goniatite-deposit on the banks of the Rhine is underlain by fossiliferous limestone and sandstones of great thickness, which there constitute the central and lower members of the Devonian series.

It seems, indeed, almost certain that there is in Russia no known equivalent of the 'Système Rhénan' of Dumont, or great 'Spiriferen-Sandstein,' which forms the fossiliferous base of the Devonian rocks of the Rhine *. This inference, indeed, is sustained by the fact that the Upper Silurian of Russia is nowhere surmounted by that band (charged with Cephalaspis and Pteraspis) which constitutes the lowest member of the Old Red Sandstone of Britain, of the lowest rocks of North Devon, and which I consider to be the exact equivalent of the Spirifer-Sandstone of Coblentz on the Rhine. That the Devonian rocks of Russia are completely independent of the Silurian, is therefore demonstrated both by their peculiar fauna, and by their reposing in one tract on Upper, in another on Lower Silurian rocks, as demonstrated by Helmersen †, Kutorga, Schmidt, and others.

In Poland also, with my associates, I traced true Devonian rocks at and around Kielce, to the south of Warsaw, with limestones and many characteristic fossils ‡. These rocks are there followed, on the west, by Carboniferous Limestones and the thick-bedded Coal-seams which extend from Russian Poland into the productive Silesian Coal-field of Prussia.

* According to M. Barrande, Goniatites occur in the Upper Silurian of Bohemia.

† In addition to Helmersen's survey of the Devonian rocks, which extend so largely throughout Central Russia, the late M. Raimund Pacht also described, in some detail, the nature of these rocks, and a portion of their fossils, as they occur in Livonia (Devonische Kalk in Lievland. Dörpat, 1849).

‡ See 'Russia-in-Europe,' vol. i. p. 39. Whilst this edition is printing I have received a memoir on the fossils of this Devonian group at Kielce by my old associate in the Carpathian mountains, Prof. Zeuschner of Warsaw (Verhandl. Kais. Min. Gesells. 2te Ser. vol. i. St. Petersburg, 1866). He enumerates twenty species of fossils, all of which are known Devonian forms.

Carboniferous Rocks of Russia.—Of the Carboniferous group, as exhibited in Russia-in-Europe, it is enough to say that its lowest members only are there well developed. In the small section above given (p. 364), we see beds of Carboniferous Limestone with traces of coal lying immediately on the red and green rocks with Devonian Fishes. To the north-east, or on the Andoma River in the Government of Olonetz, the calcareous members of this division swell out; but even the few thin seams of poor coal above mentioned disappear and are represented by one course of black and very slightly bituminous shale.

Near Moscow, efforts have been made to reach coal by boring through the superjacent Jurassic rocks (Oxfordian), which there cover the Carboniferous Limestone; but, according to Helmersen, no coal was detected at a depth of 490 feet. Ranging from Moscow by Serpuchof to Tula and Kaluga, where the Carboniferous Limestone again comes out to the surface, seams of poor coal have been partially worked at Serpuchof and other places enumerated by Helmersen; but they are of slight value only *. In the southern region of the Donetz, however, between the Don and the Dnieper, where these lower strata reappear, the coal-seams are of much larger dimensions, and several of them are of much better quality. They are there all interstratified with beds of Carboniferous Limestone, like the Scotch coal-fields (p. 293).

In the last tract, however, that horizontality of the Palæozoic strata in the northern parts of this vast country, which would have rendered the coal-beds highly valuable, no longer exists. The limestone, sandstone, and shale, with the coal, have here been violently extruded to the surface through a cover of surrounding Permian, Jurassic, and Cretaceous deposits, and, being very highly dislocated, are consequently difficult and expensive to work.

But if the Imperial Government should open out deep shafts, as I long ago suggested, by sinking through the secondary rocks to the east of the River Donetz †, the good beds of coal which she possesses in the south may be found to lie in valuable and regular masses beneath the unbroken and surrounding Secondary rocks.

Some of the grandest examples of the Carboniferous Limestones of Russia are to be seen on the banks of the Volga, near Syzran, the bend which that mighty river makes, as delineated on all maps, being caused by lofty cliffs of those rocks, which frown over the low region on the east. There, thick beds, containing numerous fossil species common to this division in many quarters of the globe, are laden with the small Fusulinæ, first noticed by Pallas, which are remarkable in being among the oldest of the Foraminifers,—the Fusulina being in truth a prototype of the Nummulite, which became abundant so long afterwards in the Tertiary deposits. No coal-seams, however, have been detected in these rocks.

Other and not less gorgeous masses of the same limestone are displayed on the western flank of the Ural Mountains, where they are united conformably in numerous undulations with underlying limestones containing Devonian fossils. Not repeating sketches which are given in another work, I would refer the reader to the woodcut at p. 366, in which masses both of Devonian and Carboniferous Limestone are seen in intimate connexion, but much dislocated at this spot, in the gorge of the River Tchussovaya on the western edge of the Ural Mountains.

* Helmersen, 'Ueber die Bohrarbeiten auf Steinkohle bei Moskau und Serpuchow,' Mélanges Phys. et Chim.: Petersburg, 1856. See also Helmersen's recent work, 'Gisements de charbon de terre en Russie:' St.-Pétersbourg, 1866.

† In the work on Russia I suggested that, if the Imperial Government should make trials for what may very probably prove to be a valuable and unbroken coal-field, sinkings should be made on the left bank of the Donets, through some of those flanking horizontal Secondary formations, not distant from the edge of the up-cast and dislocated coal-field. (See 'Russia-in-Europe,' p. 118 *et seq.*) I called the attention of the present Emperor to this important subject when I had the honour of an interview with his Imperial Majesty at Darmstadt in 1857, and when I presented sections illustrating my opinion.

The clearest proofs are thus exhibited (the two formations being quite conformable) that the portion of the series which is very slightly coal-bearing in

DEVONIAN AND CARBONIFEROUS ROCKS IN THE GORGE OF THE TCHUSSOVAYA RIVER (WEST FLANK OF THE URAL MOUNTAINS).
(From 'Russia-in-Europe and the Ural Mountains,' vol. i. p. 386).

Central Russia, and much more so on the Donetz, is entirely wanting on the flanks of the Ural.

These Carboniferous Limestones, everywhere more or less characterized by their Producti, are overlain along the western edge of the Ural chain by sandstones and grits which occupy much the same place in the general series as the Millstone-grit of England. In that region, indeed, coal has been worked on the banks of small affluents of the Tchussovaya*, near Ust Coiva and other places, in a representative of the Millstone-grit (see 'Russia-in-Europe,' vol. i. p. 126).

In Russia, however, these strata are often more calcareous, and contain Goniatites. They constitute the uppermost bands of the Carboniferons group, properly so called, in the vast territory between the Volga and the Ural Mountains, where they are seen in many localities to be at once succeeded by the Permian deposits before described. These, the highest Carboniferous beds in Russia, contain only at intervals thin coal-seams; and the great Upper Coal-measures of England have no representative in the Russian Empire.

* From the recent writings of Helmersen it appears that these coal-beds have been much opened out since I visited these tracts, and that the mineral has been discovered at various places along the upper flanks of the Carboniferous Limestone on the Tchussovaya.

In making these brief observations on the Carboniferous deposits of Russia, and in referring to the details given in 'Russia and the Ural Mountains,' I wish my readers to understand that, as it was my painful task to acquaint my kind friend and patron, the late Emperor Nicholas, with the important but disagreeable fact that all Northern Russia must ever be exempt from coal, inasmuch as the rocks which there rise to the surface are of an age anterior to the oldest formations in which coal exists, it was at the same time a pleasing duty to hold out a different prospect for the southern part of his great Empire. Thus I could well declare that there the very same limestones which are so poor in coal near Moscow assume rich coal-bearing qualities as they roll over southwards in great undulations beneath the Secondary formations, as proved by the outcrop of rich masses on the Donetz. Knowing, further, that this phenomenon extended even to Eregli, at the south end of the Black Sea, I naturally impressed upon the Imperial Government the high probability, if not almost certainty, of finding large undisturbed coal-fields beneath the horizontal Secondary rocks that occupy the flat and undulating steppes to the east of the River Donetz. (See 'Russia-in Europe,' vol. i. p. 118.)

In stating that identical formations have very dissimilar mineralogical characters in tracts distant from each other, we have only to point to different parts of the vast Russian Empire itself. Thus, whilst the soft Lower Silurian clays and sands of St. Petersburg have their equivalents in the hard schists and quartz-rocks with gold-veins in the heart of the Ural Mountains, the equally soft red and green Devonian marls of the Valdai Hills are represented on the western flank of that chain by hard, contorted, and fractured limestones, as in the preceding sketch, made in the gorge of the Tchussovaya.

The deposits of Silurian, Devonian, and Carboniferous age which have remained spread out in wide, horizontal, and slightly broken masses over Russia-in-Europe, have, we have seen, been so thrown up in the Ural Mountains as to constitute metamorphosed and highly mineralized rocks, out of whose débris the Permian deposits were formed. Other views given in a subsequent Chapter on the auriferous rocks will realize to the eye the condition of the more central and completely altered rocks of that chain. In the meantime it may be stated that hard and crystalline, or slaty Palæozoic strata, associated with numerous erupted porphyries and greenstones, form the nuclei of all the mountainous ridges in Siberia, whether in the lofty Altai on the south-east, where some of them have been well described by M. Pierre de Tchihatchef *, or in those hills which form separating barriers between the great rivers Ob, Jenissei, and Lena, and extend to the Sea of Ochotsk and Behring's Straits on the north-east. These phenomena, indeed, have been further traced over vast regions of

* See the magnificent work, 'L'Altaï Orientale,' of M. Pierre de Tchihatchef. Some Devonian fossils have been found near Lake Baikal.

Mongolia, the Kirghis Steppes, and the borders of Chinese Tartary and Central Asia, by that enterprising explorer and skilful artist, the late T. W. Atkinson, who leads us to believe that, in addition to the numerous eruptive rocks of ancient geological date, subaërial volcanos must have existed in parts of this wild, extraordinary, and hitherto unexplored rocky region *.

Grand, therefore, as is the spread of soft and slightly coherent primeval rocks throughout Russia-in-Europe, the hard stony tracts of this age which extend over the Asiatic regions of the same great Empire are much more extensive.

Restricting our view to Russia-in-Europe, we see fossiliferous Silurian and Devonian rocks rise partially to the surface in the southern provinces of Podolia, on the banks of the Dnieper; and although no rocks of such high antiquity have yet been detected in the Caucasian mountains, Devonian rocks reoccur in the same latitude near Constantinople †, and have been recognized by Tchihatcheff in several parts of Asia Minor to the south of the Black Sea ‡, and are also traced even to the southern flanks of Mount Ararat, and thence eastwards into Persia §.

Looking, therefore, to the most ancient crystalline rocks of Northern Scandinavia, which probably represent both the Laurentian and Cambrian rocks of Britain and other countries, we know that they have been overlapped successively by those Silurian, Devonian, Carboniferous, and Permian strata which occupy an enormous region in Russia. The discovery at Spitzbergen of at least one Permian fossil, identified by Mr. Salter ‖, shows how widely spread were all these primeval deposits, and how they must have been successively accumulated around a nucleus of preexisting crystalline rocks.

* See Atkinson's 'Oriental and Western Siberia,' 1858.

† See Hamilton and Strickland; Proc. Geol. Soc. Lond. vol. ii. p. 437. The Turkish fossils are of the oldest Devonian age, and represent the Spirifer-schist and -sandstone of the Rhine, which, as well as their equivalent the Lower Old Red Sandstone of Scotland, are wanting in Russia.

‡ Bull. Soc. Géol. France, 2 ser. vol. vii. p. 389. My enterprising friend Pierre de Tchihatcheff, who has for the ninth time explored Asia Minor, visiting tracts which were previously blanks on all maps, exhibited his new geological map of the whole region to the British Association at the Nottingham Meeting, 1866. Large tracts of metamorphic rocks which underlie true Devonian rocks will, I anticipate, prove to be of Silurian age.

§ Abich, Quart. Journ. Geol. Soc. Lond. 1846, vol. ii. 2nd pt. p. 96; and 'Russia and the Ural Mountains,' vol. i. p. 652. Prof. Abich also found Carboniferous Limestones everywhere overlying these Devonian rocks, and characterized, too, by a small Fusulina, of a species distinct from that found in Russia. The memoir he has published, and particularly a large work which, I rejoice to think, he is now preparing, under the auspices of the Russian Government, must throw great light on the physical structure of the whole chain of the Caucasus. In a memoir received when the last edition was coming out, M. Abich offered several critical remarks on the Map of Europe completed by M. Dumont shortly before his death, showing errata of considerable magnitude in relation to the Caucasian region, most of which pertain to rocks of Secondary and Tertiary age, not treated of in this work. He stated, moreover, that the violet colour which represents the Lower Devonian ('Rhénan' of Dumont) must be struck out as regards the tract lying between 38° and 47° E. long., all that country being occupied by very old rocks and crystalline slates. In truth, however, the Map of Dumont, one half of which is taken from the Map of Russia-in-Europe and the Ural Mountains by myself and associates, must not be judged by such ultra-European inaccuracies. Although the classification of the stratified rocks by my late distinguished friend differs from that which I adopt, I much admire the clearness and beauty of his work. For my own Geological Map of Europe (Johnston), as published with the assistance of Prof. Nicol, I claim more indulgence from my friends, as it was hastily issued, and contains many errors of detail, and is now much behind the knowledge of the day. In extending his observations to the eastward, M. Hommaire de Hell discovered Devonian rocks in Persia, where they form the axis of the Elburz chain and the southern slopes of the mountains of Tchihennene, and are highly fossiliferous in the valley of Tuva. (Bull. Soc. Géol. Fr. vol. vii. p. 500.)

‖ Quart. Journ. Geol. Soc. vol. xvi. pp. 440, 441.

CHAPTER XV.

PRIMEVAL SUCCESSION IN GERMANY.

GENERAL SKETCH OF THE CHARACTER OF THE OLDER ROCKS EXTENDING WESTWARDS FROM TURKEY-IN-EUROPE INTO THE CARPATHIANS AND ALPS.—DEVONIAN AND CARBONIFEROUS ROCKS OF POLAND, SILESIA, AND MORAVIA.—LAURENTIAN, CAMBRIAN, AND SILURIAN ROCKS OF BOHEMIA AND BAVARIA.—SILURIAN, DEVONIAN, AND CARBONIFEROUS ROCKS OF SAXONY, THE THÜRINGERWALD, ETC.

WHILST the general order of the older strata is clearly exposed in that larger portion of Russia-in-Europe which has from the remotest antiquity been exempted from the intrusion of every description of plutonic or volcanic rocks, we no sooner pass to the south-west and enter the Danubian and Turkish Provinces, than we meet with masses more or less crystalline, which, like those of the Ural Mountains and Siberia, have been penetrated at various localities by igneous matter. These extend from the Balkan into the ranges of Thrace and Transylvania on the one hand, and into the Carpathians on the other; but they have as yet been so little examined in detail as to leave us in ignorance of the extent to which a Palæozoic classification can be applied to them. From the travels of Boué, Visquenel, Warington Smyth, and others, it is known, however, that these rocks are usually so crystalline as to afford few spots like those near Constantinople, just alluded to, where the palæontologist can expect to observe even a few rare fossils.

When, however, we reach the Eastern or Austrian Alps, we find that, although most of the older strata forming a great portion of those mountains have been metamorphosed, there are certain 'oases,' at wide intervals, indicative of a succession similar to that which we have been following through other countries. Thus, in the ridge south of Werfen, in the Salzburg tract, Orthocerata, Orthidæ, Cardiolæ, and other fossils have been detected, marking a remnant of a true Silurian zone, the chief mass of which is in a crystalline state. In the Styrian Alps near Gratz, certain grey schists and calcareous flagstones contain many Devonian fossils; and similar rocks have there been traced through a district of some extent.

Near Bleiberg, in the Carinthian portion of the Eastern Alps, is a limestone with large Producti which is of Carboniferous age; whilst in various parts of the Western Alps the rocks contain courses of anthracite associated with Plants of the same era. On the whole, however, it may be said that, in nearly all the countries extending over the southern regions of Germany, the clear separation of the Palæozoic rocks, which can be easily effected in many other parts of Europe, is impracticable. This is doubtless owing, in great measure,

to numerous mutations of structure, as well as to the dislocations and inversions which all the rocks have there undergone, from the Silurian to the Tertiary inclusive.

When, however, we travel westward in a more northern parallel, and pass from the central provinces of Russia into Poland, Prussia, and the northern states of Austria, we find that, although the Palæozoic rocks of those regions have no longer the wholly unaltered facies which they presented to us on the banks of the Neva, the Volga, and the Dwina, and though, unlike their Russian equivalents, they have been penetrated by many eruptive rocks, yet they contain numerous examples of order and where the normal relations may be clearly observed.

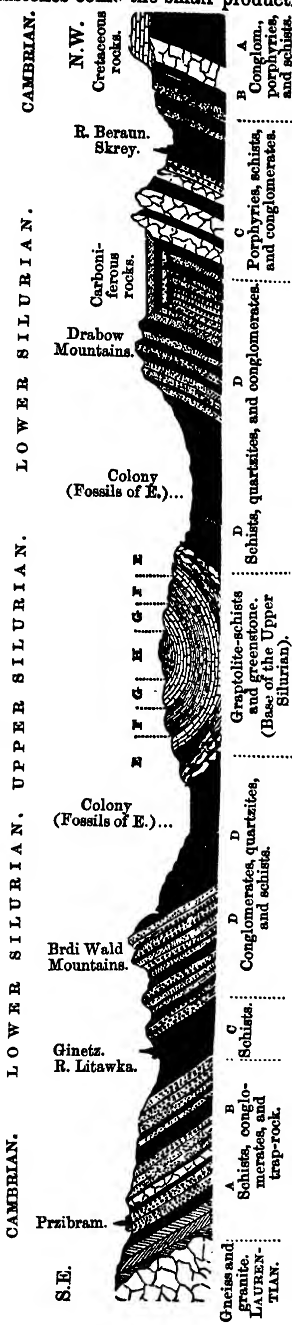
In Poland, and in many low districts of Northern Germany, so widely spread are the younger Secondary and Tertiary deposits that the rocks under consideration rise only in small patches to the surface. Thus, aronnd Kielce *, to the south of Warsaw, as before said, Devonian rocks emerge, charged with many characteristic fossils, and are followed by Carboniferous Limestone and coal-seams that range from Russian Poland into the Silesian coal-tracts of Prussia. Thence to the westward, rocks which have been classified as Silurian, Devonian, Carboniferous, and Permian occupy detached districts in Prussia, Saxony, the smaller states of Germany, large tracts in the northern territories of Austria (particularly in Bohemia), and also in parts of Moravia.

In traversing the Riesengebirge to the south of Breslau, the geologist acquainted with the full development of the Palæozoic rocks of other regions is struck with the comparative tenuity of the Devonian and Carboniferous deposits. In large portions of these mountains (the mineral characters of which have been examined in detail by Gustav Rose, whilst their geological distinctions have been explained by E. Beyrich) the strata of Silurian age have, for the most part, undergone a complete metamorphosis. They have indeed passed so generally into crystalline schist and marble, that fossils of the earlier era have very rarely rewarded the labours of the eminent men above mentioned, or of my old friends H. von Dechen and C. von Oeynhausen, who first explored that range. That these older crystalline strata are, however, the equivalents of the Silurian rocks is certain, because they have been found to contain Graptolites, and are clearly surmounted by limestone charged with many Devonian forms. In the district of Waldenburg, south of Breslau, and at Silberberg, to the north of Glatz, the Devonian limestone, having a thickness of 50 to 60 feet only, is charged with Clymeniæ and many other typical fossils. It is covered by an overlying limestone of no greater vertical dimensions, laden with large Producti and several other shells well known in the Mountain-limestone of Britain †, especially those of the Lower Carboniferous zone, the two beds being separated by thin strata of schist. This Carboniferous Limestone is overlain by rocks occupying the place of the Millstone-grit of English geologists, and which, assuming very much the same mineral characters as the rocks whereon they repose (being also perfectly conformable with them), were in old times confounded with the then undefined 'grauwacké.' It is in this portion of the series, namely in the schists and sandstones associated with the Carboniferous Limestone, that several of those Plants have been found which Professor Göppert formerly described as of 'transition age' (Calamites transitionis &c.). Above these schists

* See 'Russia in-Europe,' vol. i. p. 39.

† At one spot, Falkenberg, I collected in the Carboniferous Limestone the following fossils—Productus gigas, P. semireticulatus, Strophomena analoga, St. crenistria (var.), Spirifer lineatus, Sp. pinguis, Sp. glaber, with a minute Phillipsia, a small Orthoceras, and several species of Corals.

and sandstones come the small productive coal-fields of Waldenburg, succeeded by a copious development of red rocks (Roth-liegende), grouped many years ago by me with Permian deposits, and which have already been described (pp. 314 &c.) *.



GENERALIZED SECTION ACROSS THE SILURIAN BASIN OF CENTRAL BOHEMIA, BY M. JOACHIM BARRANDE.
(From Barrande's 'Système Silurien de la Bohème,' vol. i. p. 56 b.—See also Bull. Soc. Géol. France, sér. 2. vol. viii.; and Leonhard's N. Jahrb. 1847, pl. i.)

Again, in Moravia † the order of the older Palæozoic deposits is very analogous to that which prevails in Silesia. There I have observed crystalline schists and limestone, representing Silurian formations, followed by masses of limestone which at Rittberg and other places around Olmütz are charged with Devonian fossils. Some of the strata, in tracts that I have not seen, are referred to the Carboniferous era. The crystalline rocks which range thence, or from the Sudeten Mountains into the Böhmerwald-Gebirge, and have been generally described by Partsch ‡, Heinrichs, and others, consist of gneiss, mica-schist, chlorite-schist, and hornblendic slates, with saccharoid limestones, the whole being penetrated by granite, syenite, greenstone, serpentine, &c. Although portions of these vast masses may probably represent the Silurian series, the greater part of the schistose rocks (including limestones) in which fossils have been detected are clearly of Devonian age, as has been elsewhere shown §.

Silurian and subjacent Rocks of Bohemia and Bavaria.—If the traveller has worked his way round from Britain through Scandinavia and Russia into North-eastern Germany, and has there lost the clue whereby he could have identified the lower crystalline schists and limestones of Silesia and Moravia with their representatives in the western, northern, and eastern regions of Europe, he will indeed be rejoiced

* See 'Russia-in-Europe and the Ural Mountains,' vol. i. p. 200. I examined this tract alone, in the year 1844.

† See 'Uebersicht der Geologie von Mähren und österr. Schlesien:' Wien, 1852 (with a Map).

‡ Jahrb. k.-k. geol. Reichsanstalt, vol. i. 1851.

§ See Edinb. N. P. J. 1847, p. 66, and 'Devonische Formation in Mähren,' Leonh. N. Jahrb. i. 1841. The observations were made, conjointly with my old colleagues von Keyserling and de Verneuil, in the year 1847.

when he enters upon the territory around Prague, and there sees, under the guidance of my eminent friend M. Barrande, a most complete and symmetrical exposure of the whole Silurian System, whether as respects the clear order of the strata, or a vast abundance of organic remains.

The geologist who would form an adequate idea of the relations of this 'Bassin Silurien,' so admirably developed by that author, must traverse the tract as I have done with him, from Przibram and Ginetz on the south-east, to Skrey on the north-west, or visit the environs of Beraun. He will then at once recognize the truthfulness and accuracy of the divisions which have been established after a most indefatigable and persevering study of the rocks and their organic remains during the last twenty-seven years. The simple and regular form of this basin, and the order in which its concentric deposits are arranged, have enabled its first true explorer to ascertain the existence of three characteristic faunas, containing eight local stages, into which Barrande divides what he has there proved to be the 'Silurian System.' (See the preceding diagram *.)

Just as in the British Isles, the lowest fossil-bearing strata, c of the section, repose on vast masses of conglomerates, grits, and crystalline schists, B, A. These, which are of Cambrian age, rest upon gneiss and granitic rocks, which, in 1862, I classed as Laurentian. The argillaceous schists, c, the lowest in which fossils occur, contain Barrande's 'Faune Primordiale.' This 'Primordial' Silurian fauna is specially characterized by Trilobites of the genera Paradoxides, Conocephalus, Ellipsocephalus, Sao, and Agnostus; and it also contains a rare Orthis, a few Cystidea, and some species of Pteropods belonging to the genus Theca. According to the opinion of M. Barrande, in which I entirely agree, this zone is represented (as before said, pp. 40, 45, &c.) by the rocks containing Lingula, Agnostus, Conocephalus, and Paradoxides in North and South Wales, and also by those which in the south-west flank of the Malvern Hills contain the Olenus; whilst, as has already been noted, Olenus, together with Paradoxides and Agnostus, are typical of the lowest band in which animals have yet been found in Norway (see p. 349, 2nd section: this zone represents also the Alum-slates, or 'Regiones A, B' of Angelin). The large species of Paradoxides in Bohemia also belong to the same 'Primordial' group. To the same epoch must also be referred the similar forms which have been described, by Dr. Dale Owen, Professor W. Rogers, and others, as characterizing the lowest Silurian rocks of the eastern coast of North America.

On reexamining, in 1862, the crystalline rocks which form the central nucleus of Germany in Bohemia and Bavaria, I could scarcely fail to perceive that, just as in the north-west of Scotland, they there formed a true representative of the Laurentian System, as proved by infraposition. In fact I reentered that region already disposed to believe that this equivalent was to be recognized in the gneiss and granite described by Barrande as underlying his general ascending series.

In exploring the Bavarian or western portion of this ancient chain, I was also furnished with the instructive geological map of Dr. C. Gümbel of Munich; and with that in hand, it at once seemed to me that the ascending order from a

* Though the conclusions are stated briefly in the text, I must be allowed to say that they could have been arrived at only through intense labour and unwearied research, as well as by the liberal employment of Bohemian workmen. The last twenty-seven years have been occupied in unravelling this grand and rich Silurian fauna. To most persons the acquisition of the Bohemian or 'Czeck' language might have been an insurmountable barrier; but, finding that without this key he could not direct his workmen, M. Barrande mastered the difficulty, and made himself a Bohemian scholar in order to become a thorough geological expounder of these rocks. His Silurian collections are certainly more interesting than those ever made before by any one individual; whilst the evidences of faithful scrutiny and of a philosophical spirit which pervade all the pages of his great work are, I know, duly appreciated by every geologist and naturalist.

fundamental gneiss upwards was the same as in North America and North Britain. Hence, on my return, I announced to my colleagues in England that the two great zones of rock which Dr. Gümbel named the Bojic (or Bavarian) and the Hercynian Gneiss seemed to me to constitute one great system of enormous thickness, and that, judging from the overlying formations, it must be truly Laurentian *.

In fact these gneiss rocks in Bavaria are separated from the 'Primordial Zone' (Étage C) of Barrande, or true base of the Silurian strata, in the first place by large masses of micaceous and chloritic schists with quartzites, and next by a very great thickness of clay-slate (Ur-Thon-Schiefer), which is directly followed by the 'Primordial' Silurian zone. This position necessarily places these schists and slates (Stages A and B) precisely in the same stratigraphical arrangement as the British Cambrian of the preceding pages.

In the following year Dr. Gümbel discovered Eozoon Canadense in the marbles of the band of gneiss which he considers to be the younger (but which is also according to him analogous to the older) Laurentian of Logan, and thus he completed the proofs of the age of these gneissic deposits. With them, indeed, he classes the overlying micaceous and chloritic schists as also Laurentian. Judging, however, of these rocks by comparison with our British series of like age, I am of opinion that they are simply the metamorphosed portions of the Cambrian or slaty rocks which in Bavaria, as in Anglesea and North Wales, have been altered by the protrusion of granite. However that may be, it is in the clay-slates, which underlie everything of Silurian date, that Dr. C. Gümbel has detected another species of Foraminifer, which he has named Eozoon Bavaricum. Dr. A. Fritsch, of Prague, had already observed certain Annelide-tubes in the quartzose schists of the 'Étage A' of Barrande, near Prague †.

Having for the last quarter of a century grouped the 'Primordial Zone' as the base of the Silurian System, I am greatly indebted to M. Barrande for the important evidence which substantiated the intimate connexion of that zone with the rest of the Silurian formations.

Lying above all these enormous masses of clay-slate, the 'Primordial Zone' ‡ was discovered to the south of Hof, but presenting a remarkable agglomeration of fossils which, in the hands of M. Barrande, proved to be ordinary Lower Silurian types, but with a predominance of forms specially characteristic of the 'Primordial Zone.' Thus Calymene, Cheirurus, with Orthis and Cystidea of the Llandeilo and Caradoc formations, were commingled with many Conocephali, Oleni, and Lingulæ of the 'Primordial Zone.' The true coexistence of those types (as M. Barrande himself showed me) in the same hand-specimens was to me, therefore, the most satisfactory proof I ever obtained that I had judged rightly, after many wide surveys, in classifying the 'Zone Primordiale,' or its equivalent the Lingula- and Conocephalus-flags of Wales, as the true base of the Silurian System of life.

* See Quart. Journ. Geol. Soc. vol. xix. p. 359.

† Geol. Mag. vol. iii. p. 431.

‡ The position of this band of the 'Zone Primordiale' was given by Professor Gümbel in a section which I brought out in a memoir on the general succession in Bavaria from the Laurentian gneiss up to the Devonian and Carboniferous rocks of Hof (Quart. Journ. Geol. Soc. vol. xix. p. 354).

The process by which this important point was established was as follows:—In 1851 M. Barrande discovered fossils of this zone in the collections of Count Münster, and then visited the ground to mark their position. In 1852 he observed similar fossils brought from the same place, which were noticed by Geinitz ('Verstein. Grauwacke-Formation,' vol. ii. p. 25). In 1860 M. Barrande urged the German geologists to explore the site and thereon Professor Wirth, of Hof, made the collection in question, which he remitted to Dr. Gümbel, who transmitted it to M. Barrande for determination. In 1863 M. Barrande, in a note on the geology of the environs of Hof, explains these points in relation to the discoveries of Casiano di Prado in Spain (Bull. Géol. Soc. France, vol. xx. p. 476, vol. xvii. p. 543).

In a letter to myself in, 1863, M. Barrande made the following important observations:—

"This fauna (from the environs of Hof) presents evidently 'Primordial' characters, by the predominance and the forms of its Trilobites, which are accompanied by a small number only of the usual Lower Silurian genera, *i. e.* Lingula and Discina, the Pteropod Pugiunculus, and a Cystidean.

"The Trilobites predominate, indeed, over the other fossils, both in the number of species and in the relative quantity of individuals: I recognized eight to ten species of Conocephalus and Olenus, all new, as well as another type which also seemed to me to be new. With these 'Primordial' Trilobites are also associated two or three forms which everywhere characterize the Second Silurian fauna (Llandeilo and Caradoc), *i. e.* Calymene and Cheirurus.

"The coexistence of these different types is evident, since I found them in the same piece of rock not larger than my hand.

"The occurrence of the genus Olenus, which is entirely absent in Bohemia, and the appearances which the species of it present, indicate that the fauna of the environs of Hof has more relation to the English and northern zone than to the central zone of Europe. There was therefore (of old) a gneissic barrier, more or less elevated, between Bohemia and Bavaria, such as that which we now see.

"I was drawing up an interesting parallel between these two Palæozoic basins; but just as I was about to complete it, I was obliged to quit Prague; and since then I have been absorbed in very different occupations.

"You will observe that the partial coexistence of the Primordial and Second faunas on the frontier of Bohemia comes in very *à propos* to aid us in the conception of the partial coexistence of the Second and Third Faunas in Bohemia, or, in other words, of my 'Colonies.'"—Quart. Journ. Geol. Soc. vol. xix. p. 362.

But, to return to a description of the Silurian basin of Bohemia. The next zone, or 'Stage D,' of the typical basin of Barrande, is formed of schists and sandstones, and represents the great upper mass of the Lower Silurian, charged with abundant casts of Trinucleus, Ogygia, Asaphus, Illænus, Remopleurides, and many other Trilobites. In it also has been observed the same relative development of the genus Orthis among the Brachiopods, and of Cystideæ among the Echinoderms, which stamps the character of the Lower Silurian rocks of Scandinavia, Russia, Britain, and North America.

Prague, with its Imperial palace, the Hradschin, stands upon these Lower Silurian rocks, which, dipping under Upper Silurian schists and limestones to the south of the city, rise up again to the surface on the banks of the Moldau, a few miles further south, and thus exhibit the upper members enclosed within a trough.

M. Barrande places the base of his Upper Silurian, or bottom of his 'Stage E,' where the quartzites with Trinuclei are overlain by black schists with large concretions or ballstones, and containing many Graptolites. Several bands of greenstone, which the author considers to be of cotemporaneous age, are interpolated in this portion of the series; and the shales are followed by grey argillaceous limestone replete with a very rich fauna, unquestionably of an Upper-Silurian type. Although it might be contended, however, that, as in other countries, the schists which contain both the doubly and singly serrated Graptolites ought rather to be classed with the lower division, no one can doubt that the limestones into which those schists graduate upwards represent the true Upper-Silurian type, so well marked in England and Gothland. Thus, in these we meet with the well-known fossils Cardiola interrupta, C. fibrosa, Phragmoceras ventricosum, P. arcuatum (Cyrtoceras, Barr.), Orthoceras annulatum, O. num-

mularium, Rhynchonella navicula, Rh. obovata, Rh. Wilsoni, Rh. marginalis, Acroculia haliotis, Pentamerus Knightii, P. galeatus, Spirifer trapezoidalis, and forms of Leptæna, all of them published in my original work as Upper-Silurian species. Again, most of the Zoophytes which so characterize the Wenlock and Gothland limestone are here found in profusion, including the widely known Corals Halysites (Catenipora) catenularius, Favosites Gotlandicus, &c. Even that fossil which has not otherwise, I believe, been detected out of England, the Ischadites Kœnigii, Sil. Syst., has been here collected in great quantities. It is also in this rich Stage (E) that the Cephalopods have their maximum development, as represented by 400 species in this band only, there being among them many species of the true Nautilus. The Crustacea, Acephala, Gasteropoda, and Brachiopoda occur in about the same remarkable proportion, M. Barrande having described no less than seventy-eight species of Trilobites from this one limestone, the chief genera being Acidaspis, Calymene, Cheirurus, Cyphaspis, Lichas, Phacops, Harpes, Bronteus, Proetus, and Arethusina.

Though M. Barrande has shown that the English fauna of this division has many representative and nearly allied forms in Bohemia, the number of fossils which are actually identical in the two countries is limited. Thus the Phragmoceras ventricosum, P. arcuatum, and Orthoceras nummularium of Britain are represented respectively in Bohemia by the Phragmoceras Broderipi, Cyrtoceras Murchisoni, and Orthoceras docens of Barrande. In this rich formation, Stage E, the Cephalopods alone amount to about 600 species, three-fourths of these belonging to Cyrtoceras and Orthoceras!

Judging from the fossils, Mr. Salter is of opinion that the subdivision *d* represents the Llandeilo formation; and other beds and their fossils have been compared with the Caradoc. For my own part, however, I have always thought that geologists should not endeavour to synchronize any one British subdivision with an exact equivalent in distant foreign lands; and in Bohemia the simple divisions of lower and upper, as adopted by M. Barrande, are, I think, quite sufficient.

Ascending from this limestone (E of the section, p. 371), the remaining and superior stages of calcareous rock (F and G) are so entirely conformable, are so often closely knit together in parallel folds in the same hill with the Stage E, and are so connected zoologically as well as stratigraphically, that M. Barrande has united them all in one natural group, as containing his Third Fauna. The band F, a thin-bedded, hard limestone, usually of a light colour and somewhat crystalline, and therefore offering a strong contrast to the dark and earthy rock of the beds beneath it, is particularly distinguished from Stage E by a great diminution in the number of Cephalopods, which class continues still to diminish in the earlier part of the Stage G, but augments again largely in the calcareous zone forming the upper or later part of the band. It is indeed remarkable that several animals which seemed to be extinct, such as Gomphoceras and Phragmoceras, reappear in forms very similar to those of the Wenlock formation (E), very much lower down. They coexist with Goniatites, fossils wholly unknown in any stratum below the Stage F.

I must refer the reader to the remarkable data brought forward by M. Barrande (Défense des Colonies, Part iii. pp. 314, 315) which demonstrate that there is more specific connexion between the Stages E and F and a Devonian fauna than the last bears to his highest Stages G and H. This is one of the valid reasons assigned by the author for upholding the truthfulness of the migration of certain marine animals in 'Colonies', which after an interval returned

to their former habitats—a view which, as applied by this great geologist, is as original as it is in consonance with natural-history data relating to the migrations of marine animals (see p. 380). This Stage (F) is characterized by the first appearance of true Goniatites, which, as far as I know, have not been observed in so low an horizon in any other part of the world. Some of these, indeed, are larger than any previously known Goniatites. All intervening bands of shale and schist disappearing, the band F is at once surmounted by the highest limestone G—a rock usually of small concretionary structure, but which when laid open, as in large quarries on the banks of the Moldau (Branik, Wiskocilka, &c.), exhibits extensive flattish masses with slightly undulating surfaces, the upper layers of which are covered by grey shale, H of the diagram (p. 371). In these two uppermost stages nearly all the other classes of fossils expire; but many Trilobites still prevail in them.

M. Barrande refers all these three limestones, including their shales, inferior and superior, to the Upper Silurian group, since he has found (as, indeed, I long ago anticipated *) that the British division into Wenlock and Ludlow rocks was not be looked for in distant lands. In truth, he has detected abundant Ludlow-rock fossils in the lower limestone E; and though the upper Stages, F, G, H, contain some of the same species as that rock, they are also distinguished by many which are locally peculiar to each of them. In this way Stage F is marked by its profusion of Brachiopods; whilst the Cephalopods, so abundant in the lower limestone, are reduced to a few. Of Trilobites, though there are seventy-five species, they all belong to the same genera as those of Stage E.

In G, or the highest limestone, there would seem, at first sight, to be some reason for classifying this mass rather as Devonian, seeing that, as well as the rock beneath, it contains Goniatites, a genus of Cephalopods unknown in the Silurian of Britain, but abundant in the Devonian and Carboniferous rocks of many countries. This one feature, however (and the Bohemian species are peculiar, and not known Devonian, types), cannot prevail, in the opinion of the author, in the face of the much more decisive fact that many true Silurian types pervade the three limestones, and unite them in one natural group. Thus we here meet with forty species of Trilobites of the genera before mentioned, with the addition of Dalmanites (Phacops). Now, although all these genera, with the exception of Calymene, are known in the Devonian rocks, no one of the Bohemian species has been found in them †; and the resemblance is therefore confined to the Brachiopod shells, of which a few species are certainly found in Devonian strata ‡.

Appended to his work § is an invaluable Table (plate 51, vol. i.), containing the result of as much philosophical thought and profound research as were ever embodied in a single page of natural-history; and in it M. Barrande brings proof at once before the eye, that every one of the few Devonian Trilobites belongs to a genus which took its rise and had its maximum development in the Silurian period. In other words, they are only the expiring remnants of the Crustaceans of the first great natural epoch in which those animals flourished. M. Barrande has also defined the upper limit of Silurian life by showing that his highest limestone contains three species of Calymene, a genus never yet found in the Devonian rocks, the form which was originally taken for a Calymene in the lowest Devonian of the Rhine being now recognized as a Phacops.

* See 'Silurian System,' pp. 196, 301, *et passim*.

† I have the authority of M. Fridolin Sandberger to state that he knows of none of the Upper Silurian Trilobites of Bohemia in the Devonian rocks of the Rhine.

‡ Barrande on the Silurian Brachiopods of Bohemia, in Haidinger's Naturwissensch. Abhandl. 1847, vol. i.

§ 'Système Silurien de la Bohême,' vol. i.

In short, about 2735 species of fossils have already been obtained through the labours of this naturalist in working out the rich materials of his Silurian Basin; and as in Britain and other parts of the world, so in Bohemia, the most assiduous researches, aided by the microscope, have failed to detect the trace of a vertebrated animal below the uppermost Silurian rocks. In the two highest bands of these, and notably in the uppermost only, has M. Barrande obtained fragments of Fish-bones. It is further remarkable that he has found the peculiar Crustacean Pterygotus, ranging, as it does to a great extent in England, through the Upper Silurian rocks (pp. 237 &c.). See also Sil. Syst. pl. 4, and p. 606.

The geologist who compares this edition of 'Siluria' with the first, will have already perceived, p. 47 *et seq.*, that in the years which have elapsed, many new or additional fossils have been detected in the lowest stages of the Llandeilo rocks, chiefly in the Silurian region of England and Wales, as well as in the crystalline quartzites and limestones of Sutherlandshire (p. 165).

Now, just in this interval of time has M. Barrande discovered, at the same horizon in his Silurian Basin of Bohemia, a fauna which much resembles that of the same old British zone. Thus Æglina prisca, Barr., resembles very nearly Æglina binodosa, Salter, of the Stiper Stones (p. 48); whilst the Redonia of Rouault has its representative in the British form (fig. 2. p. 48); and Ribeiria pholadiformis, Sharpe, which characterizes the Lower Silurian of Portugal, and is matched by our R. complanata (fig. 3. p. 48), makes its first appearance in Bohemia in this Stage. Let us also mark that here, as in Shropshire, Graptolites and Orthoceratites are associated in the same zone with the above-mentioned Mollusca, and that one of the Bohemian Orthocerata has a striated surface similar to that of our Orthoceras Avelinii (p. 48. fig. 4).

But notwithstanding the unmistakeable analogy between the 'Second Fauna' and that of the Llandeilo and Caradoc formations of England, M. Barrande is of opinion that it is impossible to identify any one of his subdivisions with any particular English stratum. He believes this applies equally to his 'Zone Primordiale' and to his 'Third Fauna' (Etage E). At the same time he points out that the successive apposition of the fossils is essentially the same, but with some notable differences. Thus, among the Cephalopods, the first Cyrtoceras appears in Wales in the Tremadoc Slates; there are six or seven species in the Llandeilo beds and two in the Caradoc formation. In Bohemia, on the contrary, there is no trace of a Cyrtoceras in all the Second Fauna (Etage D) to represent the British Llandeilo and Caradoc fossils, though there are two species in the 'Colonies.' Again, Orthoceras vaginatum, or its representative, with a large marginal siphon, which occurs in the British Caradoc, is only found in the very lowest bed of Etage D—that is, quite low in what we may consider to be the equivalent of the Llandeilo rocks. Whilst, therefore, the chief Lower Silurian formations are the same in both countries, the details of the development in each differ materially. In Britain we as yet know of no species which mounts up from the Lower Llandeilo to the Llandovery rocks; but in the Bohemian basin nine or ten species of the lowest band of Etage D ('Second Fauna'), after disappearing in the three overlying bands, reappear in the uppermost strata. M. Barrande in his work on the 'Colonies' of fossils, points out with great effect the recurrence of the same phenomenon in the Upper Silurian, *i. e.* his 'Third Fauna,' and says that the same thing occurs in other countries.

M. Barrande has also met with another link which binds together the northern type of Russia, Scandinavia, and England with that of Bohemia, in a species of

large Orthoceras of the group O. duplex (p. 357), so eminently characteristic of this age in the North of Europe. He has, in short, detected about sixty species in this zone, a portion of which he has tabulated *. Among these fossils we perceive the remarkable Cephalopod with step-like septa, the Bathmoceras, Barrande, together with a large Ogygia, Calymene Arago, and Bellerophon bilobatus,—the last, which is so typical of these rocks in Britain and France, being very abundant. It is also worthy of notice that Agnostus tardus, Barr., which had hitherto been recognized in the upper division only of Stage D, makes its first appearance in these much older beds. Here also appears, for the first time, Graptolithus priodon (colonus, Barr.), which does not play the same part as in Britain by living on through so long a lapse of time (see p. 125); for, whilst in Wales and Shropshire the latter was in existence from the period when the slaty rocks of Snowdon were formed to the time of the Ludlow deposit, this same fossil in Bohemia, with all its congeners, reappears no more above the Stage E of the Bohemian basin. Again, among the fossils of this zone there are Orthidæ of three species, a small Euomphalus? (E. primus, Barr.—belonging rather to the many-whorled genus Ophileta of Sutherlandshire and Canada), several species of Cystideæ and Ophiuridæ, with Encrinites, as well as forms of the little Entomostracite Beyrichia, which characterizes vast breadths of Upper and Lower Silurian rocks in many countries, even in the Arctic Regions. Already, therefore, in this very ancient stage, we find many of the types which range through the whole Silurian System!

The overlying Stages of the great Lower Silurian deposits of Bohemia, or the four upper subdivisions of Barrande's Stage D, correspond on the whole to the remainder of the Llandeilo Flags and all the Caradoc formation. But the same mineral characters are so persistent throughout the series of numerous bands of quartzite, and similar courses of schist are so repeatedly interlaced with them from the base to the summit, whilst so many fossils are common to the whole, that it has not been found practicable to mark the same distinctions as in Britain. Among the fossils which most prevail may be mentioned Beyrichia Bohemica, Acidaspis Buchii, Placoparia Zippei, Theca elegans, and Ribeiria pholadiformis,—the last having lived on from the earliest-formed strata of this group (D).

Let me here add a few more words on some striking features of the organic remains of this Bohemian basin. Among the Graptolites, G. priodon (Ludensis, Sil. Syst.), which in England is found in all the Silurian rocks, is beautifully preserved,—its smaller end being incurved. Of Corals there occur quite as many Silurian forms as are known in England. The Cystideæ of the Lower Silurian (Stage D) are occasionally of great size; and some of them, like the Echino-encrinites of Scandinavia and Russia, ascend into the Stage E, or Upper Silurian.

The profusion of Chambered Shells in the basin of Prague has enabled M. Barrande to trace many gradations between the generic types Gomphoceras, Phragmoceras, Trochoceras, Cyrtoceras, &c.; and in two specimens of Orthoceras he has detected the animal matter in the state of adipocere! These bodies, therefore, he justly considers to be the oldest mummies ever exhumed, since they occur in Lower Silurian rocks with Trinuclei! The most ancient Nautilus yet found is probably N. tyrannus, Barr., a huge form of a genus of which the author has traced some members through all their stages of growth. There are some Goniatites, of forms approaching Nautilus; but no species, not even in the very highest strata near Prague, is a known Devonian type.

* Bull. Soc. Géol. Fr. sér. 2. vol. xiii. p. 532.

Besides the genera of Trilobites enumerated as occurring in the 'Primordial' or lowest zone, that band also contains the Hydrocephalus, so named by Barrande from its inflated head, and the Arionellus, a large flat form, which Prof. Angelin has recognized in the same zone in Sweden. In the succeeding mass of the Lower Silurian, or Stage D, is found Beyrichia lata, common also to Sweden and America. Acidaspis Buchii has been described also by M. Bertrand Geslin from rocks of this age near Nantes; whilst other Entomostraca, chiefly bivalved (of which there are about twenty species), range from the lowest to the highest of the Upper Silurian limestones.

Space does not permit of an examination of the analogies and identities prevailing among the Brachiopods and Gasteropods of the basin of Prague as compared with those of Silurian age in other countries. Suffice it to say that, when fully elaborated, the whole of the fossils will probably amount, under the discrimination of M. Barrande, to upwards of 2000 species! *

Other results of the researches into the contents of the Bohemian basin show just those agreements in the general distribution of life and the peculiarities of local arrangement which are found in all synchronous deposits. Thus the Pterygoti in Britain ascend from the Llandovery to the Ludlow rocks; and in Bohemia they range upwards from Stage E, or the representative of the Wenlock formation.

Again, the Asteriadæ, or Star-fishes, which are rare in what may be called the Llandeilo rocks, or Barrande's subdivision D^1, become conspicuous in the higher stage D^4, or Caradoc. They have the same range in Britain and Canada.

Notwithstanding their strict conformity to each other, the Lower and Upper Silurian rocks of Bohemia are supposed to be more sharply separated from each other by differences of their fossils than in the wider area of the British Isles. This fact may to a great extent be explained by an appeal to the usual phenomenon of a clear separation of types wherever a limited tract only is surveyed.

Here, however, we have another cause, by which M. Barrande accounts satisfactorily for the specific separation, in this tract, of the animals of his three Silurian zones. He shows that, after the accumulation of what he calls the 'Primordial Zone,' the sea-bottom of this region was powerfully disturbed by the eruption of porphyries. Again, after the completion of his Second Zone, or at the close of the older Silurian period, other igneous rocks (greenstones &c.) were so copiously and repeatedly evolved as to account for the destruction of nearly all the animals then living in this area, the creatures which were enabled to exist and live on during such turbulent conditions being for the most part Graptolites.

Yet even from this point of view, the author of the 'Bassin Silurien de la Bohème' has proved that not less than sixty species of fossils are common to his Stages D and E. Thus, when the observer is working his way up through the Lower Silurian schists and quartzites of the Stage D, with their Orthidæ and Trinuclei, in them he unexpectedly meets with intercalated bands of dark shale, mineralogically similar to those of the upper Stage, and in which, out of sixty-seven discovered species, sixty are forms that characterize the Upper Silurian Stage E. This is the more remarkable, as the fossils otherwise known in the Stage D are by no means similar to those of the overlying rocks.

M. Barrande, broaching an original theory, has suggested that these schists, so insulated among the older strata, must be regarded as having been the seats of 'Colonies' of animals which, existing in some other part of the world whilst

* Geologists will do well to consult the beautiful suite of Silurian fossils from Bohemia in the British Museum, collected, classified, and arranged by M. Barrande.

the Lower Silurian fauna prevailed in Bohemia, were carried to these spots by currents, and thus for a time inhabited the region before the more general introduction of exotic species at a subsequent period (see also p. 375).

Some geologists would endeavour to explain the fact by showing that fossil animals are frequently associated with particular physical conditions, disappearing and reappearing with changes of the sea-bottom. The difference between this view and that of M. Barrande is, that he considers his ancient 'Colony' to have migrated from remote seas, where his Third or Upper-Silurian Fauna already flourished*.

Having now fully reconsidered all the evidence brought forward by M. Barrande in his well-reasoned memoirs, I am of opinion that he has fairly substantiated the soundness of his view of the former migration of species from seas more or less distant—in other words, that animals having deserted certain waters, and migrated to other localities, returned long after and under favouring conditions to the region they had long before inhabited.

In his general comparison of the Silurian fauna of Bohemia with that of Britain, M. Barrande shows, as before said, the impossibility of identifying each of the bands of his rich basin with the subdivisions established in the original Silurian region. He justly recognizes only the great divisions of Lower and Upper Silurian, placing in the earliest of these his First and Second Faunas, and his Third Fauna in the latter. With this general agreement (the application may be made to very distant tracts containing rocks of this age), it now appears certain, from M. Barrande's clear explanation of the relations of the Bohemian strata and their respective contents, that his Second Fauna, the representative of the Llandeilo and Caradoc of Britain, without any mixture of other remains, is superposed to a band containing animals which belong to his Third Fauna, or Upper Silurian. This fact sets aside the inference that his 'Colonies' may represent the Llandovery rocks of British classification, and shows that in Bohemia it is impracticable to establish a 'Middle Silurian,' as suggested by Mr. Salter when I was preparing the last edition of 'Siluria.' Irrespective of the ingenious establishment of the natural-history fact of the migration of animals, it is clear that these alternations of life indisputably connect the Lower and Upper Silurian rocks in one system, through an interchange of a considerable number of their respective fossils. M. Barrande justifies me, indeed, in not employing the term 'Middle Silurian;' for although I have fully recognized the Llandovery rocks as occupying a transitional place in my own country, I well know that there are many tracts in which no such evidences exist; and the reader who refers to the table on the side of the coloured map will at once perceive that the Upper Llandovery is bracketed as the base of the Upper Silurian, and the Lower Llandovery as the summit of the Lower Silurian.

The fossil species collected by M. Barrande in his rich Bohemian basin are thus enumerated:—Fishes, 5 (1 in Stage F, and 4 in Stage G, both equivalents of Ludlow rocks); Trilobites, 350; Crustacea, 70; Cephalopods, 870; Pteropods, 70; Gasteropods, 550; Bivalves, 450; Brachiopods, 220; Polyzoa and Polyps, 150. Total, about 2735 species.

Before I take leave of this rich centre of Silurian life, which my eminent friend has rendered so classical, let me invite the attention of the reader to one salient proof of his acumen and sagacity as a naturalist. Every one knows that living Crustaceans, from the King-crab (Limulus) and Lobster downwards, proceed from eggs; and before reaching maturity, many of them, even of

* See 'Bulletin Soc. Géol. de France,' vol. xvii. p. 639, and vol. xx. p. 492; also Barrande, 'Défense des Colonies.'

the highest grades, are known to pass through a metamorphosis. Now, M. Barrande has discovered, after examining multitudes of specimens, that the Trilobite or earliest Crustacean underwent a similar metamorphosis from the embryo to the adult state, and passed through many changes of form. In the genus Sao, for example, he has distinguished no less than eighteen stages of development of the same species, each stage being marked by an addition to the thoracic ribs of the animal; and he has thus taught us, by true natural proofs, that several so-called genera and many species named by cotemporary authors really belong to this one creature *. The same analysis of forms has, indeed, been extended by M. Barrande to other and higher deposits of the Silurian system; for he has indicated twenty-two changes in his beautiful species Arethusina Koninckii of the Stage E; and altogether he has found the phenomenon to hold good in thirty-four species of Trilobites in the Lower and Upper Silurian strata, there being seven metamorphoses in the genus Trinucleus alone! He has even followed out his subject into other families, and has traced the fossil Nautilus from the egg, through twenty variations of form, to its completion with a perfect aperture to the shell!

In a word, the work of M. Barrande will convince every one who studies it that we have now obtained quite as clear an insight into the earliest stages of life yet recognized upon the globe, as into the succession of those younger deposits the secrets of which are so much more easily wrung from the less indurated stony records of nature.

Palæozoic Rocks (Silurian, Devonian, Carboniferous, and Permian †) of Thuringia, Franconia, Saxony, and the adjacent Principalities.—The older sedimentary formations occupy a considerable region on the north-western flank of that devious chain of granitic, gneissose, and other crystalline rocks which, ranging from north-east to south-west, divides Saxony from Austria, and trends into the Fichtel-Gebirge of Bavaria. From that chain the deposits in question descend into and spread over a broad and comparatively low, undulating tract, which in its central part is cut through transversely by the River Saal as it flows from Hof on the north-east to Saalfeld on the south-west. On their western boundary, these sedimentary rocks again constitute some of the lofty eminences of the Southern Thüringerwald, the whole succession under consideration having a dominant strike from south-west to north-east. In this way the younger strata may be said to occupy a broad trough, ranging lengthwise from Ronneburg and Gera on the north-east, by Schleitz, Plauen, and Hof, to Upper Franconia on the south-west; whilst the older rocks of the series, rising up on either side, are often in a highly metamorphic state, but chiefly on the south-eastern flank of the depression.

The first effort to coordinate the various sedimentary rocks of this region with their equivalents in the Rhenish Provinces and the British Isles was made in the year 1839, by Professor Sedgwick and myself ‡. We commenced our survey by examining the mountainous elevations of old grauwacké in the Southern Thüringerwald, and thence extended our observations to the younger shelly limestones of Upper Franconia, wherein Count Münster had collected his 'transition' fossils. As the result, we indicated that which has proved to be the true general succession. We spoke, for example, of a slaty greywackè with greenish slate and quartzose flagstones and grits like those of the Longmynd,—of quartz-

* See particularly Corda, 'Prodromus einer Monog. der Böhmischen Trilobiten,' in which the species Sao hirsuta, Barr., has been divided into no less than ten genera, and these again subdivided into eighteen species!

† For details of the Permian rocks of these tracts, see p. 313 *et seq.*

‡ Trans. Geol. Soc. Lond., 2nd ser., vol. vi. p. 296.

ites and roofing-slates with a greenish tinge (Schwartzburg, &c.), that reminded us of the lower slates of Cumberland and Westmoreland. The whole of them were said to exhibit great undulations, but with a prevalent dip to the south-east,—to be powerfully affected by a slaty cleavage,—and to be surmounted by subcrystalline limestones with alum-slate (pyritous shale of Doschnitz, &c.). These, again, were described as covered by other grey schists and greywackè, containing also courses of limestone; and all such beds disappeared, we said, under more earthy and arenaceous strata, resembling the Devonian rocks of the Rhenish Provinces. Finding, however, no fossils except Encrinites in the lower part of these rocks, we could assign to them no more definite place than that they were probably of the age of the slates of the Ardennes. On the other hand, we regarded the fossiliferous limestones of Franconia (Elbersreuth, Hof, Gattendorff, &c.), which are replete with Clymeniæ, Goniatites, and Orthocerata, as being unequivocally of Devonian age; and, lastly, by actual sections, we confirmed the view of Count Münster derived from fossils only, and showed that the limestones and associated schists of Trogenau, Regnitz Losau, and Würlitz near Hof were truly of the age of the Carboniferous or Mountain Limestone *.

In calling attention to this view of the succession, which, in a subsequent visit with Professor Morris, I found to be correct, it is by no means contended that Professor Sedgwick and myself did more than throw out a general suggestion; for at that time, not only was there no true geological survey of this complicated country, but not even any ordinary geographical map which could be depended on. In the quarter of a century which has since elapsed, good trigonometrical surveys have been made of large portions of the region; able geologists of Saxony and Meiningen have likewise constructed geological maps, and have described many fossils entirely unknown in earlier days.

Thus Professors Naumann, Cotta, and Geinitz, in Saxony, and M. Richter of Saalfeld in Meiningen, have elaborately worked out the demarcation of the mineral masses of which these old rocks are composed; and some having been found to contain Graptolites, Trilobites, and other ancient fossils, such inferior greywackè has very properly been referred by those authorities to the Lower Silurian †. With this view I quite agree, guarding the definition of the word 'Lower Silurian' by explaining that some of the black schists of this region which contain Graptolites may be of the age of that zone which forms the base of M. Barrande's Upper Silurian in Bohemia.

The following, therefore, may be taken as a view of the succession, completing the first sketch by Sedgwick and myself:—

1. Ancient rocks of the Thüringerwald, consisting of greenish talcose schists with white quartz-veins, which in former times afforded some gold. They range from Steinheide by Igleshieb, or from south-west to north-east, in association with certain bands of ferruginous and purple-coloured greywackè not

* The fossils collected in these limestones were Productus punctatus, P. antiquatus, P. sublævis, P. pustulosus, a large Orthis near to O. crenistria, Phill., Chonetes papilionacea, Euomphalus pentangulatus, and several Corals of the genera Syringopora, Cyathophyllum, &c.,—a perfectly Carboniferous assemblage.

† I must not omit to add to this list the name of M. Engelhardt of Ober-Steinach, who has made a large collection of fossils, some of which are manifestly of Lower Silurian, and others of Devonian age. The strata near that place are so dislocated and in great part inverted, that I can well understand how that gentleman, from whom I experienced every courtesy when I visited Steinach, should have been led to indicate an order of strata whereby the rocks which are really Devonian were placed under the Lower-Silurian greywackè. The formations referred by him to the Upper Silurian, under the names of Wenlock, Aymestry, Ludlow, &c. (Zeit. deutsch. geol. Gesellsch. Berlin, vol. iv. p. 234), are for the most part Devonian, as proved by fossils; but, not relying on my own judgment only, I obtained the opinion of M. Barrande, which confirmed my own views.

unlike the bottom rocks of the British sections described in the Second Chapter of this work. These masses occupy the highest grounds of the Oberland of Meiningen, attaining an elevation of nearly 3000 English feet above the sea. 2. The beds of this lofty plateau fold over both to the north-west and south-east, and are throughout affected by a slaty cleavage, which extends to all the overlying formations. As the planes of this cleavage, usually plunging to the north-west at a high angle, are dominant, and often obliterate the lines of true bedding, they have misled some observers with respect to the physical succession of the strata.

Attentive observation, however, convinced me that, rolling over in undulations to the south-east, the above rocks ('Grüne Grauwacke' of Richter), containing the Fucoid (?) Phycodes circinatum, Richter, and the pygidium of a Trilobite, are overlain by the group which Richter terms 'Graue Grauwacke.' The latter is composed of much slate, with hard siliceous sandstone, courses of limestone, and some alum-schists, one portion of the slaty rocks being extensively quarried for the manufacture of slate-pencils (Criffelstein). The lower beds exhibit fine examples of so-called Fucoids, among which are Fucoides Alleghaniensis, together with Myrianites, and the Graptolites (?) Cladograpsus nereitarum, Nereograpsus Sedgwicki, and N. Cambrensis (Nereites *, Sil. Syst.). The upper beds especially contain Graptolites, Orthoceratites, and some forms of Trilobites. Of the truth of this succession I convinced myself by examining, with M. Engelhardt and Professor Morris, that portion of the section of Ober-Steinach which pertains to the Silurian rocks. A species of Trilobite found by M. Engelhardt approaches near to, if it be not identical with, Ogygia (Asaphus) Buchii, whilst a form of Maclurea collected by M. Richter closely resembles M. magna, Hall; and, as some of the worm-like bodies (Nereites), and several of the Graptolites, both double and single, are not distinguishable from forms known in the British Isles, there can be no doubt that we have in this slaty group a true equivalent of a Lower Silurian formation, and probably of Llandeilo age.

The positive identity of the Thuringian strata with their equivalents in Britain has been further established by the occurrence, not only of the same species of Annelide or large Nereites, as above noticed (see the woodcut, p. 201), but also of Protovirgularia dichotoma, specimens of which Richter has detected in Germany, apparently identical with those found in the Lammermuir Hills of Scotland.

It would further appear that there are strata in the Southern Thüringerwald which by their fossils approach to the Caradoc and Lower Llandovery rocks of Britain; for Richter has shown† that, together with Trinucleus, Phacops Stokesii is present, as well as Pentamerus oblongus and P. globosus. With these also are the well-known British Lower-Silurian fossils, Euomphalus Corndensis, Orthis testudinaria, O. alternata, O. lata, Leptæna sericea, &c., some of which are Lower Llandovery species.

The upper beds of alum-slate and flinty slate are principally characterized by Graptolites, several of which are species identical with those described by Portlock, Salter, M'Coy, Harkness, Nicol, and myself, chiefly from the Lower Silurian of Britain; and among these, as seen in the work of Geinitz, or identified by Richter, are the following:—Diplograpsus folium, His.; D. palmeus and D. ovatus, Barr.; D. teretiusculus, His.; Graptolithus priodon, Bronn; G.

* Geinitz regards these as belonging to the Graptolite family.
† Zeitschr. der deutschen geol. Gesell. 1853, p. 439; ib. 1854, p. 275, note.

Sedgwickii, Portlock; G. Beckii, Barr.; G. latus, M'Coy (?); G. spina, Richt.; G. turriculatus, Barr.; G. Nilssoni, Barr.; G. sagittarius, His.; G. colonus, G. Proteus, and Rastrites peregrinus, Barr.*; with some other species common to this region and Bohemia, including the remarkable form Retiolites Geinitzianus, Barr. Several of the Graptolites are similar to those of the Silurian deposits of Scandinavia, North America, and other countries.

The researches of M. Richter have, indeed, gone further, and have enabled me to speculate upon a close approach to the Upper Silurian, if he has not really made known the base of that division. For among the remains of one of the courses of limestone, he has detected Cardiola interrupta, Brod., Acroculia prototypa, Phill., with Orthoceras styloideum and O. Bohemicum of Barrande, both of which characterize the 'Stage E' of that author.

The Silurian rocks of the Thüringerwald and of the Saalfeld tract, which are penetrated at intervals by porphyries and greenstones, are irregularly overlapped, towards their south-eastern flanks, by masses of Devonian age (the 'Rothe Grauwacke' of Richter), which will be considered presently. Silurian schists containing Graptolites again emerge from beneath younger strata in a series of low undulations far to the east of the lofty and wooded Thüringerwald. The base, in fact, of the low ridges extending from Ronneburg on the north-east, through Schleitz, to Lobenstein on the south-west, is composed of graptolite-schists and roofing-slates. Similar rocks reappear in parallel undulations in the environs of Plauen and Hof; and it is probable that considerable portions of the 'Thon-Schiefer' of the Geological Map of Saxony will hereafter be found to belong to the Lower Silurian division.

The exact demarcation of the outline of these Silurian formations, and their separation from all the older unfossiliferous and crystalline strata on the one hand, and from the Devonian rocks on the other, will be a work of no small labour. Their regular order has been repeatedly interfered with by erupted and pseudo-volcanic masses, which, whether they constitute stratified layers or appear as intrusive bosses, have singularly affected the ordinary sediments. These igneous rocks are indeed most accurately laid down on the map by Professor Naumann and his associates. So rapidly does the geologist here proceed from one formation to another, that a single small hill composed of Lower Silurian schists with Graptolites is often contiguous to the Upper Devonian limestone. These changes are well seen near Schleitz, where the low ridges of black brittle schist, which form the pleasure-grounds of the reigning Prince (Heinrich's Ruhe), are laden with Graptolites, Orthidæ, and other fossils of Lower-Silurian date†; whilst, on the western side of an intervening small hill of eruptive rock, the geologist has before him a limestone charged with Clymeniæ, Cypridinæ, and the very uppermost Devonian fossils! On the whole, however, it may be said that, although they occupy so broad an area in the lofty tract of the Thüringerwald, the Silurian rocks only make their appearance partially, and within comparatively narrow bounds, in the central portion of that region which has here been designated a vast undulating trough. Even then one characteristic band is alone visible, composed of the black schists and slates, extending from Ronneburg by Schleitz to Lehestein and Lobenstein.

The Devonian rocks of this portion of Germany, previously known by the

* See some of these forms of Graptolites, p. 61, and Plates I. and XII. of this work.

† All the Silurian fossils from this spot figured in the work of Professor Geinitz had been found by M. Berner, of Schleitz, who, it appears, detected Graptolites in these strata many years before the attention of geologists was called to them.

palæontological labours of Count Münster, have recently been much more fully illustrated by Geinitz and Richter.

The lands being densely wooded, it is exceedingly difficult to trace any absolute junction of these Devonian rocks with the subjacent Lower Silurian of the Thüringerwald. That they lie, however, irregularly upon their older neighbours is manifest from the faithful delineation of their outlines in Richter's geological map, in which the Devonian, or the 'Rothe Grauwacke' of that author, constitutes patches or hummocks only, in relation to a great spread of the more ancient rocks*; and that this is their true position I can affirm from observation.

The extent to which this Devonian group of Thuringia, Franconia, and Voigtland can be paralleled in its details with that of the Rhenish Provinces of Prussia is not yet completely ascertained; for, beginning with what is now usually recognized as the lowest fossiliferous rock of the Rhine, or the 'Spiriferen-Sandstein,' I have not been able there, any more than in Russia (p. 364), to detect such strata infraposed to the fossiliferous limestones.

The next question then is, can we even divide the Devonian of this region in Central Germany into lower and upper limestones, as is done in Devonshire and the Rhenish Provinces?

This separation has, indeed, been partially made by Geinitz, who places at the bottom of this group certain schists near Ronneburg, which Naumann has identified in several other localities. These schists contain Tentaculites lævigatus, Römer, and T. subconicus, Gein., with Phacops. Then follow certain limestones near Plauen, Wildenfels, and other localities, including the well-known Elbersreuth, which are also classed as older Devonian. These are characterized by Orthoceras interruptum and O. dimidiatum, Münst., Clymenia lævigata and C. linearis, Münst., Corals, and Crinoids. Then succeed stratified igneous rocks, some of which are greenstones, others coarse trappean breccias, and others, again, finely levigated ash-beds, occasionally calcareous and undistinguishable from the 'Schaalstein' of the Rhine (Plauschwitzer-Schichten of Naumann). Above these lies the Clymenia-limestone, properly so called, in which many fossils abound, including Goniatites and several species of Posidonomya (P. inversa and P. regularis, Goldf., &c.), together with a vast profusion of the little bivalved Entomostracan known as Cypridina serrato-striata, Römer. Not professing to have worked out the proofs of all these subdivisions, I must say that, in those tracts which I have examined, there are no evidences of two Devonian limestones, separated from each other by slaty rocks as in England and on the Rhine.

In short, I have nowhere seen in Saxony, or the adjacent districts, a full representative of the Eifel Limestone as characterized by its Stringocephali, Calceolæ, &c., overlain by another which represents the Clymenia-rock of England

* See Beitrag zur Paläontologie des Thüringer-Waldes, von Reinhard Richter (Dresden and Leipsic, 1848); and Die Versteinerungen der Grauwacken-Formation in Sachsen, &c., von Hans Bruno Geinitz (Leipsic, 1853). In the first part of his able work, Professor Geinitz describes and figures many species of Graptolites, before referred to, p. 383; and in the second he adds to these the following Silurian fossils:—Nereograpsus tenuissimus, Emmons; Orthoceras Bronguiarti, Troost; O. tenue, Wahlenberg; Leptocheles (Ceratiocaris?) Murchisoni, Agass.; Tentaculites tenuis, Sow.; Pterinea Sowerbyi, M'Coy; Nucula lævata, Hall; a Cytherina (?), and Orthis callactis, Dalm. These fossils, however, are very obscure, and their identification therefore doubtful. In the Devonian rocks he describes one genus of Trilobite (Phacops) only, of chambered shells 24 species (including Orthoceras, Gomphoceras, and Cyrtoceras), Clymenia 6, Goniatites 4, Gasteropods 8 species, Lamellibranchs 24 species, Brachiopods 11 (including the universal Atrypa reticularis), of Crinoids 9 or 10 species, and about 11 kinds of Corals are also enumerated.

Several other Brachiopods are described by Richter in a more recent paper ('Thüringischen Schiefergebirge.' Zeitschr. deuts. geol. Gesells. Jahrg. 1866), where no less than twelve species identical with our Wenlock and Ludlow shells are mentioned, besides the well-known Bivalves Cardiola interrupta and C. striata. They are Spirifer plicatellus, Spirigerina (Athyris) obovata, Sp. (Atrypa) reticulatus, Atrypa Grayii, Rhynchonella deflexa, Orthis callactis, O. calligramma, Strophomena pecten, St. imbrex, Leptæna lævigata, L. lata, and Orbiculoidea Forbesii.

(the Kramenzel-Stein of the Rhine). M. Geinitz, however, has detected in the strata inferior to the Cypridina-schists the following fossils, all of which are found in the Eifel Limestone:—Favosites cervicornis, Edw. and Haime; Stromatopora concentrica, Goldf.; Fenestella subrectangularis, Sandb.; Productus subaculeatus, Murch.; Chonetes minuta, de Kon.; Atrypa reticularis, Linn.; Terebratula (?) elongata, Schloth.; and a large species of Phacops. But, as towards the end of this Chapter we shall indicate that those two calcareous masses which are so clearly separated in some districts are nearly brought together in others, it is possible that the divisions partially indicated through their fossils by Geinitz may be established in Voigtland, and the igneous tuff (Schaalstein) of Plauschwitz and other places may, as he believes, separate these two rocks.

However this may be, the ascending order, in several localities, is clear, from a highly fossiliferous and nodular limestone, laden with Cypridinæ, Clymeniæ, Goniatites, and Orthoceratites, and which is clearly Upper Devonian, into associated strata in which Land Plants begin to appear. The Devonian limestone is surmounted by a copious accumulation of sandstones and schists, occasionally siliceous—the 'Jüngste Grauwacke' of Geinitz, charged with terrestrial vegetable remains. These are sometimes followed by the Carboniferous Limestone or 'Kohlen-Kalk' with its large Producti, and by other strata containing a different series of Land Plants.

Such an ascending order is seen at Hof, on the right bank of the Saal, between the town quarries, replete with Cypridinæ, and an overlying coralline limestone. This succession is still clearer between Gattendorf and Troguenau, the intervening space between the Clymenia-limestone (Upper Devonian) of the former and the Productus-limestone (Carboniferous) of the latter being occupied by ferruginous grauwacké with traces of Plants, and by a mass of 'Kiesel-Schiefer,' which there occupies the same place as the rock so called by the geologists of the Rhine country *.

Again, in the gorge of the Saal, near Saalfeld, the cliffs (which Richter has described in a published section †) expose a magnificent mass of limestones, characterized throughout by Cypridina serrato-striata, Sandb., and C. calcarata, Richt., with other Upper-Devonian types, but which offer no evidence whatever of a second limestone between them and the Lower Silurian rocks. Here the same geologist has detected Phacops latifrons, Bronn, P. granulatus, Posidonomya minuta, and P. intercostalis, Röm., with trails of worm-like animals. Here also (no igneous rocks appearing) the ascending order seemed to me to be clear and unequivocal. In spite of the dominant slaty cleavage, the planes of which dip to the north-west, the Cypridina-limestones, after those fine convolutions which render the gorge so picturesque, are seen to pass under the mass of red rocks, or 'Rothe Grauwacke' of Richter ‡, the whole being covered unconformably by terraces of Zechstein.

The lower part of this reddish sandy and schistose flagstone is interlaminated with the Cypridinen-Schiefer, the mass of which immediately succeeds to the limestone; and from this point the beds begin to contain Land Plants, which

* Much confusion may arise in comparing the local descriptions of German geologists, from the use of mineral terms applied to rocks. Thus, in this region of Thuringia and Saxony, 'Kiesel-Schiefer,' which here usually designates some of the older Silurian schists and also some Devonian beds, might be strictly applied to the flinty schistose strata overlying the Cypridina-limestone and its greywacké near Hof, and which are unquestionably on the parallel of the so-called 'Kiesel-Schiefer' of the Prussian and Hessian geologists —i. e. of the date of the Lower Carboniferous formations.

† Beitr. Paläont. des Thüringer-Waldes, pl. 1: Dresden, 1848.

‡ I convinced M. Richter of this fact, by closely scrutinizing the section in company with him.

augment in quantity and size in the overlying or younger strata. These consist, first of reddish and grey, and then of greenish shale, of considerable thickness, which on the right bank of the Saal extend from the cliffs of Bohlen by the Pfaffenberg to the Kleitsch Hill, and finally, at the foot of the Rothenberg, are surmounted by ferruginous micaceous flagstones, containing a great quantity of fossil Plants. I direct particular notice to this section, because it exhibits, more clearly than any other known to me, the extent to which the Land Vegetation augments as we ascend in the Devonian rocks.

The lowest Plants, as discovered by M. Richter in the Cypridina-schists, consist, according to Professor Unger, to whom they were referred, of many species belonging to new or undescribed genera, and even to new families. Some of them are considered to be intermediate between Ferns and Equisetaceæ; others seem to be primitive forms of Cycads and Conifers, possessing characters of which (says the Professor) no one has as yet had an idea; and one presents such a singular organization, that he terms it the 'prototype of the Gymnosperms'! This is the genus Aporoxylon of Unger, a Coniferous Tree which has only simple wood-cells, without the disks usual in plants of this order. In some of these Conifers the resin even has been preserved. The above are figured in his important memoir*, where also are enumerated from the same beds:—several species of the Calamiteæ—of the genera Haplocalamus, Calymma, Calamopteris, Calamosyrinx, and some of a more solid structure (Calamopitys); a few forms of the genera Cyclopteris, Sphenopteris, Dactylopteris; besides several genera founded on the stems of plants. There is also a Lepidodendron, L. nothum, probably identical with one from Caithness (see p. 269, Foss. 73. f. 4).

This section is still further interesting in demonstrating a passage upwards into other and overlying beds beneath the Rothenberg—viz. into the micaceous sandstones and flagstones, which, on account of their flora, must be classed with the Lower Carboniferous rocks. Such, for example, are Calamites transitionis, Göpp., Megaphytum (Rothenbergia) Hollebeni, Cotta, with Knorria, &c. (plants which are well known in the Rhenish Provinces of Prussia, where they invariably occupy the Lower Carboniferous rocks, and never occur, like the group above mentioned, in the Devonian, properly so called). Here, then, on the edge of the Thüringerwald, M. Richter has collected data to prove, by fossil Plants alone, a succession from the Devonian to the Carboniferous period.

Having called the attention of that author, on the spot, to the importance of applying these facts respecting the distribution of fossil Plants to the tracts between Saalfeld and Schleitz, in parts of which such remains were for the first time observed in one of my excursions †, I learn from him that he has considerably extended the area which is occupied by the Lower Carboniferous rocks in that country, as defined by its terrestrial vegetation. In fact, the ground between Saalfeld and Schleitz is all laid down in the geological maps of Saxony under one colour, or as 'older grauwacké'; whereas a very large portion of it must now be assigned to the Lower Carboniferous formation. When will my valued friends, the mineralogists and geologists of Germany, abandon a word which has led to such endless confusion? I cannot but regret that a work of such ability as one issued by Geinitz should bear the title of the 'Fossils of the Grauwacké-formation,' under which name he groups together a vast series, including Silurian, Devonian, and even Carboniferous rocks.

* 'Beitrag zur Paläontologie des Thüringer-Waldes,' by R. Richter and Franz Unger, in Denkschr. der Math.-Nat. Classe der kaiserl. Akad. der Wissenschaften zu Wien, vol. xi. 1856.

† The observation was made by M. Richter and Baron von Baumbach, in company with Professor Morris and myself.

Plant-bearing rocks also occupy a considerable strip of elevated country at the southern extremity of the Thüringerwald between Sonneberg and Teuschnitz; and they occur in abundance in the gorge of the Steinach River, north of Köppelsdorf. As they offer a good ground for geological demarcation, I strongly urged M. Credner to distinguish his 'Jüngste Grauwacke' from all its older associates which bear that unmeaning family name. As it will, of course, require much accuracy of local observation to draw the line between the plant-bearing rocks of Devonian and those of Carboniferous age, it will best become the progressive state of science not to attempt to draw any rigorous line between them, but to shade off on a map the colour of one rock into that of another, thus imitating the succession of nature, in which there can be no error.

Such is an outline of the Palæozoic succession of the last-mentioned diversified region of Central Germany, the complete elaboration of which calls for the full employment of the able men who are occupied in working out its highly interesting features. A slight allusion only has been made to the south-eastern flank of the great undulating trough of Plauen, Schleitz, and Hof; for, although Naumann and his associates have shown in their maps that older and more crystalline rocks appear, we have yet to learn how much of their 'primary clay-slate,' or 'Ur-Thonschiefer,' is to be grouped with the lower members of the series we have been considering. Other inquirers may seek to ascertain to what extent many of these ancient schists and slates, evidently of sedimentary origin, have been converted into mica-schists, and even into the metalliferous 'gneiss,' amid which the illustrious Werner taught his lessons at Freiberg.

It would seem presumptuous that a passing geologist should here hazard an opinion antagonistic to long-received ideas: still I venture to state that much of the so-called 'primitive gneiss' in the plateaux around Freiberg is of a very different age from that of the Laurentian gneiss of America, Scotland, Bavaria, and Bohemia. I would indeed suggest that those portions of it which are separated by wayboards, and exhibit several of the features of bedding and jointing of aqueous deposits, will, like the quartzites and mica-schists of the north-western region of Scotland (p. 169), prove to be of no higher antiquity than some of the Lower Silurian formations.

In the meantime, if we reason upon the fact that no Upper Silurian rocks exist here (abstracting from that category certain graptolite-schists, which may be considered their base), we may surmise that this region was raised above the waters and constituted dry land during a long period, and was afterwards depressed to great depths to receive accumulations of the Devonian era, at a period when, and in localities where, the bottom of the sea was powerfully agitated by volcanic action.

This country also contains clear evidences of a phenomenon to which Professor Sedgwick and myself called attention in 1839—namely, that whilst the 'older grauwacké' (now known to be Lower Silurian), together with the Devonian and Lower Carboniferous series, have partaken of the

same movements of elevation, contortion, and dislocation, all these lower rocks have been abruptly separated from the Upper Coal-strata.

This great physical rupture, which pervaded Germany and France, and has been duly noticed by M. Élie de Beaumont, has, however, its well-defined limits even in Europe; for, grand as it may be, the phenomenon is local only, and has not extended to Russia on the east, or to Britain on the west.

The reader must also be reminded that the region of Central Germany which has been most adverted to exhibits clearly the intimate dependence of physical outline on eruptive igneous agency. In the Thüringerwald, and, as will presently be shown, in the Harz, all these older rocks, terminating with the Lower Carboniferous strata, which have the original impress of a strike from N.E. to S.W., were so affected by the grand eruptions of porphyry and other igneous masses which prevailed in the earlier part of the Permian era, that both chains then acquired directions at right angles to the original strike of their oldest strata.

CHAPTER XVI.

PALÆOZOIC ROCKS OF THE HARZ, THE RHENISH PROVINCES OF PRUSSIA, AND BELGIUM.

UPPER SILURIAN, DEVONIAN, AND CARBONIFEROUS ROCKS OF THE HARZ.—DEVONIAN AND CARBONIFEROUS ROCKS OF THE RHINE AND ITS AFFLUENTS.—DEVONIAN AND CARBONIFEROUS DEPOSITS OF WESTPHALIA AND BELGIUM.

In advancing westwards from Central Germany, by the Harz *, to the Rhenish Provinces of Prussia, the geologist loses all traces of the Lower Silurian rocks of Bohemia, Saxony, and the Thüringerwald; whilst, with a little Upper Silurian, the Devonian and Carboniferous deposits become vastly more expanded. Yet, with this absence of the oldest fossiliferous strata, the regions under consideration present as venerable an exterior, and contain rocks possessing quite as crystalline a structure, as those of which we have just taken leave. For, if we first glance at the range of the Harz—that shrine at which many poets have worshipped Nature in fantastic forms, and where the German geologist long regarded his old 'Grauwacké' as a mass the order and age of which could never be defined,—its chief portions were first ascertained by Sedgwick and myself † to be of no more remote antiquity than the Devonian era.

The giant Brocken itself, sanctified by many an ancient legend, is a mere upstart, compared with the surrounding eruptive masses, which disturbed the bottom of the primeval sea. That mountain is composed of two kinds of granite, which, having burst forth long after the slaty rocks of Carboniferous age had been accumulated, has through ages of decomposition been arranged into those chaotic piles or 'Felsen-Meere,' so graphically described by Leopold von Buch. Again, subsequent outbursts of porphyry, during the accumulation of the Permian deposits, were also manifestations of the subterranean forces which produced the last great elevation of the Harz, and gave to the chain as well as the surrounding Secondary formations their present outline; for, unlike the prevalent north-east and south-west strike of the older rocks in most parts of Eu-

* I first visited the Harz in 1830, and secondly in 1839,—on both occasions in company with Prof. Sedgwick; and the general order of the chain, which we published in 1839, has proved substantially correct,—subject always to that reformed interpretation of the exact relative value of the various sedimentary rocks which is now applied to this tract and the Rhenish Provinces. By referring to that instructive work, the 'Palæontographica' of Dunker and Hermann von Meyer, the reader, in obtaining much information respecting the fossils of the Harz, as described by Adolf Römer, will perceive, at p. 71, vol. ii. part 2, how inverted and confused the order of succession appears. My next visit was in 1854, when Prof. Morris was my companion (see Quart. Journ. Geol. Soc. Lond. vol. xi. p. 409); and my last excursion to the same tract was in 1857, accompanied by Prof. Rupert Jones. On my own part I am bound to state that the doubt expressed in a note, p. 362, of the first edition of this work, concerning the existence of Upper Silurian rocks in the Harz, has now been removed, and that, in any fresh issue of the Geological Map of Europe, I will endeavour to represent (if the small scale admit of it) the existence of Silurian as well as of Devonian and Carboniferous rocks in the Harz.

† See Trans. Geol. Soc. Lond., 2nd ser., vol. vi. pp. 283 &c.

rope, the geographical direction of the Harz is from north-west to south-east; and thus, like that of the Thüringerwald, as before noticed (p. 314), its appearance upon a map is not derived from its ancient mineral nucleus, but from the unconformable and enveloping younger strata.

Just as many of the slaty fossiliferous rocks and limestones of the Harz are known to be of the same age as those of Devonshire (the Coccosteus of the Scottish Old Red having been found associated therewith), so another suggestion * of Sedgwick and myself has been verified, and the rocks of these eastern hills are now proved to be of older date. In the tracts around Harzgerode, and in spots near Ilsenburg, as well as in the Lauther-Thal in the Western Harz, fossils have been found by M. Bischof, M. Jasche, and M. Adolf Römer which leave no doubt that these districts are occupied by Upper Silurian rocks; and, although the fossils of these tracts are nearly all of species unknown in Britain, they belong, as a whole, to Barrande's uppermost Silurian zone of Bohemia.

Having elsewhere shown † the general relations of the strata which I considered to be of Upper-Silurian age in the Eastern Harz, I would only add that, on revisiting that tract in 1857, accompanied by Professor Rupert Jones, I was confirmed in the accuracy of that view. It is, I reaffirm, quite true that the schistose rocks with intercalated fossiliferous limestones near Mägdesprung, Harzgerode, and Alexis Baden rise out conformably from beneath a vast thickness of superincumbent strata which, ranging towards Blankenrode, and dipping to the east, must be considered of Devonian age.

The fossils of these underlying rocks, many of which had been previously figured by Ad. Römer ‡, have been recently well compared and identified by C. Giebel of Halle §. They consist, according to the latter, of Trilobites of the following eight genera—Harpes, Proetus, Cyphaspis, Phacops, Dalmania, Lichas, Acidaspis, and Bronteus. On the whole, these Crustaceans, though bearing a very close resemblance to those of the Upper Silurian of Prague, are not, in Giebel's opinion, absolutely identical. An Orthoceras and a Serpulite are also of new species. The genus Acroculia gives 13 species; Tentaculites, 2 species; Pterinea, 2 species; Lima, Venus, and Ctenodonta, each 1 species; Spirifer, 9 species; Atrypa, 2 species; Rhynchonella, 8 species, including the well-known Rh. Wilsoni; Pentamerus, 3 species, including P. Knightii, Sow., and P. galeatus, Dalm.; Orthis, 3 species; Strophomena depressa, Dalm., and another species; Leptæna, 5 species; Chonetes, 1 species; Discina, 3 species. The Crinoids are Actinocrinus lævis, Mill., and a Rhodocrinus. The Zoophytes are of the genera Aulopora, Pleurodictyum (?), Palæocyclus, Cyathophyllum, Alveolites, Dania, Chætetes, and Beaumontia, with Graptolithus and Retipora. Besides these fossils, three undescribed species of Fishes and three or four species of Plants are enumerated, one of which is of large size; but whether these latter are of land or marine origin has not been determined.

In his conclusion respecting the age of the ninety-six fossils which he specifies, M. Giebel makes the following classification. Of decided Devonian species, or those known in other places, there are five species only, and two others which are common to Silurian and Devonian; whilst eighteen are identified as Upper-

* Trans. Geol. Soc. Lond. ser. 2. vol. vi. p. 300.
† Quart. Journ. Geol. Soc. Lond. vol. xi. p. 431.
‡ Dunker und von Meyer's Palæont. vol. ii.
§ Zeitschrift für die gesammten Naturwissenschaften, Jan. 1858, no. 1: Halle.

Silurian types, chiefly those of Bohemia. When we add to these data the striking fact that a Graptolite has been found by M. Bischof in the slaty schists east of Harzgerode, and that M. Ad. Römer has detected Graptolithus priodon, Bronn, with other species of that genus in the slaty schists of the Western Harz and in other parts *, there can no longer be any doubt that, although their limits are not yet defined on any map, the Upper Silurian rocks have a real existence in this chain. A large portion, therefore, of the tracts laid down as 'Culm' in Adolf Römer's Geological Map of the Harz must, as that author has candidly stated, be changed to Silurian, whilst other parts of this so-called 'Culm' will pass into the Devonian group. Besides the underlying Upper Silurian rocks, the hill of the Rammelsberg near Goslar is known to be of the oldest Devonian age (Spiriferen-Sandstein), whilst the limestones and iron-ores around Elbingerode, and certain masses in the Lauther-Thal, at Abtenau &c., are proved by their fossils to be of the Middle-Devonian or Eifelian age †. These are succeeded, first by Upper Devonian, and next by slaty masses formerly included in the 'Grauwacké' of the Germans, but which Sedgwick and myself first identified with the Lower Carboniferous of Britain, and notably with the Culm of Devonshire. Referring to our old memoir ‡ for the establishment of that identification, I may say that many years must still elapse before the demarcation between these deposits can be even approximately defined in a region so replete with disturbances, and in which fossils are detected at wide intervals only.

In truth, through the combination of many disturbing causes, the chain of the Harz has literally been riven into detached fragments, the relative age of which can very rarely be proved by order of superposition, and can be interpreted only through a close examination of the organic remains of each broken mass. In the Rhenish Provinces, on the contrary, though large portions of their strata are infinitely contorted and broken, and sometimes even inverted, the Northern or Westphalian frontier exhibits a perfect and complete succession of formations in their normal and ascending order. The reader's attention will therefore be now directed to that region.

Palæozoic Rocks of the Rhenish Provinces of Prussia, and of Belgium.— The convoluted and broken rocks presenting such an antique slaty aspect, and, crowned with castles, forming the chief features of the gorges of the Rhine and the Moselle, exhibit nowhere any fossiliferous band so old as the Upper Silurian of the Harz. This remark applies to all the territory on the right bank of the Rhine, from the Taunus Mountains on the south-east, to the Coal-fields east of Düsseldorf on the north-west, and also to a large portion of Belgium. This vast tract of formerly undivided 'Grauwacké,' including the Duchy of Nassau, and having its northern frontier in Westphalia, is bounded on the east by the Secondary rocks of Hessia, which range southwards by Marburg and Giessen to Frankfort. On the left bank of the Rhine, the same upward succession occurs between the Lower Devonian rocks of the Hundsrück on the south-east, and the Coal tracts of Aix-la-Chapelle and Belgium on the north-west. It is only by deflecting westward into the mountainous tract of the Ardennes, that

* 'Graptolithen am Harze, von Prof. Fr. Ad. Römer,' Leonhard und Bronn's Neues Jahrbuch, 1855, p. 540, plate vii.

† See Quart. Journ. Geol. Soc. Lond. vol. xi. p. 439.

‡ See Sedgwick and Murchison, Trans. Geol. Soc. Lond. ser. 2. vol. vi. pp. 235 &c. 1839.

we meet with those older slaty rocks, rising from beneath all the other deposits, to which allusion will presently be made.

Although this view of the age of the Rhenish strata has for some years prevailed among scientific men, it is right to explain how it has happened that the English geologists * who, in the year 1839, applied to these Rhenish rocks the classification they had worked out in their own country, and thus changed the views of their precursors, should in their turn have seen reason to admit the value of certain important corrections made by their successors.

The clear general views of the Nestor of continental geologists, d'Omalius d'Halloy †, the remarkable work and map of Dumont, as well as the previous labours of Prussian geologists, including the maps of Leopold von Buch, Hoffmann, von Dechen, and von Oeynhausen, unquestionably led the way in the succession of efforts through which our present knowledge has been obtained. After the publication of the above works, Professor Sedgwick and myself endeavoured to show that, like Devonshire and Cornwall, the Rhenish Provinces contained a great mass of those strata, intermediate between the Silurian and Carboniferous deposits, which we had called Devonian—the equivalent of the Old Red Sandstone of Scotland and Herefordshire. Our cotemporaries have admitted that in our excursion of one long summer in Germany Sedgwick and myself succeeded in proving the existence of such an intermediate series in Belgium, Prussia, Franconia, and the Harz, and also in showing how on the right bank of the Rhine the 'Uppermost Grauwacké' was divisible into Lower Carboniferous and Upper Devonian rocks. Misled, however, by our interpretation of some of the lowest fossils (for at that time the Lower-Devonian forms were only partially known, and those which had been obtained were not rigidly examined), we adopted the belief that the 'lower fossiliferous grauwacké,' or that which has since been called the 'Spiriferen-Sandstein' of the Rhine, might be an equivalent of the uppermost Silurian. I have, however, for a very long time been convinced, through the palæontological labours of Ferdinand Römer and the brothers Sandberger, that the types of the lower Rhenish subdivision are quite distinct from those of the Ludlow rock, and even of the Tilestones, and are in perfect harmony with the lowest Devonian group of other countries. In admitting this amount of former misapprehension, let me say, however, that the sections by Sedgwick and myself, representing the succession of the mineral masses, have all proved to be correct. In the superior portions of the group, however, now recognized as Devonian, the geologists and palæontologists of Prussia, Nassau, and Belgium have made subdivisions, both mineralogical and zoological, which it is essential to notice.

In two recent visits to my old ground, it is satisfactory to have ascertained that all the knowledge acquired since 1839, when our first survey was made, has but confirmed and completed that identification of the rocks of the Rhenish Provinces with those of Devonshire which was then proposed by my colleague and myself; for it now appears that not some only, as we thought, but all the Palæozoic strata of Devon have their equivalents on the banks of the Rhine and in Belgium; so that, starting from the North Foreland of the Bristol Channel, and ascending into the heart of the culm- or coal-fields of Devon, as de-

* See Sedgwick and Murchison, Trans. Geol Soc. Lond. ser. 2. vol. vi. p. 211.

† See the Geological Map of France and Belgium prepared by M. d'Omalius d'Halloy in the time of the first Napoleon.

scribed p. 272, the geologist has really before him the successive representatives of the several Rhenish and Belgian deposits.

The reader who may refer back to the sixth volume of the 'Trans. Geol. Soc. Lond.' p. 252, will therefore understand that all the Rhenish ground which is described or coloured in the map and sections as 'Upper Silurian' was soon afterwards classed with the Devonian rocks. In their admirable descriptions of the Devonian fossils, MM. d'Archiac and de Verneuil have but to add the one plate of the so-called Silurian fossils to their thirteen plates of true Devonian types, and all the general features of our labours are in agreement with the latest observations.

In truth, if the field-geologist makes his survey faithfully, and establishes a correct order of superposition, his physical facts will eventually be found to coincide with the zoological evidence. Of this the Rhenish Provinces and Belgium have afforded the best illustrations; for, notwithstanding the opinion of my distinguished cotemporary, the lamented M. Dumont, who too much undervalued fossil evidence, it is essentially the study of organic remains which has led to the clear subdivision of the vast mass of older rocks which were there formerly merged under the term 'Grauwacké.' The authority of M. de Koninck will be cited in the sequel in support of views similar to my own.

Ascending Series in the Rhenish Provinces and Belgium.—The slaty masses of the Ardennes, or the oldest rocks of the region ('le Terrain Ardennais' of Dumont), may be considered Lower Silurian; for, though their fossils are very rare and obscure, they are unconformably surmounted by the lowest Devonian strata, thus leaving no place for the Upper Silurian rocks.

M. Hébert *, indeed, has shown that certain fossils (for the most part very imperfect) of the rocks in which I formerly observed Homalonoti and traces of Shells, then thought to be Silurian, are similar to those of Nehou in Normandy, and hence that the beds immediately covering the fossil-bearing slates of the Ardennes are really the base of all the Devonian rocks. This conclusion is in unison with the belief expressed to me by my distinguished friend H. von Dechen, so competent a judge of the relative age of all the rock-masses of this region, and, as will presently be seen, is amply sustained by M. de Koninck.

Neither in the gorges of the Rhine between Bingen and the mouth of the Lahn, where the rocks have been highly contorted and much subjected to slaty cleavage, nor in the quartzose ranges of the Taunus and the Hundsrück, has any one been able to detect true Silurian fossils. On the contrary, the identification of the limestone of Stromberg on the south edge of the Hundsrück with the Eifel Limestone †, and the discovery by Fridolin Sandberger of certain fossils (by no means lowest-Devonian species) along the northern edges of the Taunus, have substantiated the views originally embraced by Professor Sedgwick and myself. Commencing our inquiry, however, where the order of superposition, aided by palæontology, diffuses a clear light, we find in the Rhenish countries the following ascending series of the Devonian rocks properly so called:—

Lower Devonian or 'Spiriferen-Sandstein,' and Wissenbach Slates, &c.—Slaty schists, with interpolated sandstones and quartzose rocks, with a rare trace of impure limestone, rise up in numerous folds from beneath all the adjacent strata in the gorge of the Rhine between Coblentz and Caub. This is the 'Aeltere Rheinische Grauwacke' of F. Römer, the 'Spiriferen-Sandstein' of Sandberger,

* See Bull. Soc. Géol. de France, deux. sér. vol. xii. p. 1165.

† Ferdinand Römer and Fridolin Sandberger agree in this opinion.

and the 'Système Rhénan' of Dumont. This mass being on the whole very schistose, and having a very pronounced transverse slaty cleavage, the true undulations of the beds can be recognized by practical geologists only; still the distinction between cleavage and stratification is clearly to be seen.

These rocks contain many remarkable fossils, among which may be noticed the large and broad-winged Spirifers Sp. hystericus and Sp. speciosus, Terebratula Archiaci, many species of Pterinea, some Orthides, especially O. circularis, Leptæna plicata, Chonetes semiradiata, Sow. (C. sarcinulata, Schloth.?), Pleurodictyum problematicum, Phacops (Cryphæus) laciniatus, Ph. latifrons, and both smooth and spinose species of Homalonotus—H. Ahrendi and H. armatus, &c.*

According to all the Prussian geologists, the thin band of the Wissenbach Slates, with its numerous small pyritized Orthoceratites and Goniatites, the chief of which are Orthoceras (Bactrites) gracile, and Goniatites compressus, overlies the Spirifer-sandstone. In admitting that the fauna of this slaty band is rather peculiar, MM. Sandberger affirm that it contains from eight to ten species like those of the Spirifer-sandstone; among which are Ctenodonta solenoides, Goldf., Phacops laciniatus, Röm., and P. brevicauda, Sandb. Thus, by means of their imbedded organic remains, a natural union subsists between these two rocks, which in the Rhine country constitute the Lower Devonian †.

This Lower Devonian mass—at least, all that portion of it which is characterized by broad-winged Spirifers—was long ago recognized ‡ as extending largely over the Prussian Provinces on the left bank of the Rhine, which are watered by the Moselle, the Lieser, and the Ahr. Spreading over vast tracts east and west of Coblentz, it comprises the Système Coblentzien and Système Ahrien of Dumont; for the very same fossils pervade both these districts watered by the Rhine and the Ahr, and the distinction attempted to be drawn by the eminent Belgian geologist between these two so-named deposits was founded on mineral distinctions only.

Middle Devonian of the Rhine ('Eifel Limestone' and 'Younger Rhenish Grauwacké' of Ferd. Römer; 'Lenne-Schiefer' of von Dechen).—The strata succeeding to the Lower Devonian on the right bank of the Rhine, like the previous beds, consist of schists and sandstones; but lenticular-shaped masses of limestone prevail at intervals. They there occupy a wide tract which is watered by the Agger, Vohne, and Lenne. The Lenne-schists of von Dechen, as laid down in the splendid new geological map of the Rhenish Provinces, occupy a broad tract of country, particularly on the right bank of the Rhine. After various undulations, and with many associated bosses of erupted igneous rocks, these strata, which are charged with much iron-ore, plunge on the right bank of the Rhine under the great band of limestone which, ranging by Elberfeldt and Schwelm to Iserlohn, and appearing also at Paffrath and Refrath near Cologne, is the well-known equivalent of the chief or upper band of the Eifel Limestone. A laborious examination of the country by M. Ferd. Römer led, however, to the separation of these strata from the lower division or the 'Spiriferen-Sandstein,' and has shown that they are united with the Stringocephalus or Upper Eifel Limestone which covers them. It has, in short, been found that, whilst they contain few species in common with the underlying rocks, they are

* The Homalonotus Herschelii, 'Sil. Syst.,' a fossil formerly sent to me from the Cape of Good Hope by Sir John Herschel, and all the spinose forms of this genus, are now known to belong to Lower Devonian and not to Upper Silurian rocks. (M. Sandberger in Neues Jahrb. 1852, p. 581; and Messrs. Sharpe and Salter in Trans. Geol. Soc. ser. 2. vol. vii. p. 204.)

† In the Caub Slates, which are intercalated in the sandstones of the lower division, the MM. Sandberger have found Phacops laciniatus, with P. latifrons, Homalonotus planus, and some Orthoceratites.

‡ Trans. Geol. Soc. ser. 2. vol. vi. p. 280.

laden with fossils of the upper limestone. Hence the Prussian geologists, von Dechen, F. Römer, and Girard, have delineated these strata separately on exquisitely finished geological maps of the Rhenish Provinces of Prussia, the result of infinite research, applying to these rocks the name of 'the Agger and Lenne group' *. This subdivision is another of the many proofs which patient inquiry has brought forth to demonstrate that it is not possible to form correct geological groups by appealing to mineral characters and superposition only.

It is now known that the 'Agger and Lenne group' is identical with those schistose courses on the left bank of the Rhine which, chiefly underlying the Upper Eifel Limestone, are known as the 'Calceolen-Schiefer.' There they are characterized by the presence of the Calceola sandalina, Cryphæus (or Pleuracanthus) punctatus, Cr. stellifer, Spirifer cultrijugatus, Sp. speciosus, Cyrtina heteroclita, and many other fossils which are common both in the Eifel country and in some of the limestones of South Devon. In following these formations into Belgium, a similar order of superposition is found to prevail.

Chief Eifel Limestone.—This is the great central calcareous mass which gives to the Devonian rocks their dominant and independent characters; for, whilst the Lower Devonian of the Rhine exhibits, in some of its forms, analogies only to the Upper Silurian type, the limestone to which we have now ascended, and the approach to which is clearly indicated by the fossils in the preceding strata, contains a fauna which is unmistakeably peculiar, and wholly unlike that of the Silurian below or the Carboniferous rocks above it. One of the most striking Rhenish types of this rock is Stringocephalus Burtini, which is mainly characteristic of that which is now considered the uppermost band, as at Paffrath and Refrath on the right bank of the Rhine. The other prevailing fossils are Uncites gryphus, Davidsonia Verneuilii, Spirifer undiferus and Sp. lævicosta, Megalodon cucullatus, Lucina proavia, Murchisonia bigranulosa, and the Corals Cyathophyllum cæspitosum, Favosites polymorphus, Heliolites porosus, &c.

Laden with a profusion of Corals, Crinoids, and other fossils, many of which have been made known through the beautiful work of Goldfuss, it is unnecessary here to dilate further on the numerous organic remains of this limestone, many of which are common, as before said, in Devonshire. It may, however, be stated that, in the Eifel country as well as in the Harz, Coccosteus and other Ichthyolites have also been detected, which, as in Russia (see p. 362), serve to identify the rock as an equivalent of the central member of the Old Red Sandstone of Britain. Among the organic remains are likewise several types which connect this band with the subjacent strata of Spirifer-sandstone, such as Phacops latifrons, Bronn, and Cryphæus punctatus, Steininger, with Spirifer speciosus, Schloth., Sp. cultrijugatus, Röm., &c.†

Upper Devonian of the Rhine ('Clymenia-' and 'Goniatite-limestone,' von 'Buch' and Münster; 'Cypridinen-Schiefer,' Sandb.; 'Kramenzel-Stein' and 'Flinz' with 'Spirifer-Verneuilii-Schiefer,' &c., von Dechen).—The researches, however, of the able palæontologists to whom allusion has already been made, and those of Prof. de Koninck in Belgium, have led to a clear separation of the lime-

* This beautiful Map, which consists of 30 large sheets, 'Geognost. Karte der Rhein-Provinz und Westphalen,' is one of the noblest memorials of the school of Leopold von Buch, the great geological cartographer of the period; and whilst it does infinite honour to the Director of the Survey (my eminent and valued friend, Geheimrath H. von Dechen) and his associates, is also a proof of the enlightened encouragement of geological science by the Prussian Government. In the first edition of this work it was stated that a portion of the map had been executed by Dr. Girard, now Professor at Halle.

† See the comparative table of Adolf Römer, Geol. Kenntn. Nordw. Harzgebirges in Dunker und von Meyer's Palæontographica, vol. iii. p. 1, 1850. Also the memoirs of MM. Sandberger, Versteinerung. Rhein. Schichtensyst.: Nassau, 1850. And Frid. Sandberger, Geol. Verhältn. Nassau (with map): Wiesbaden, 1847, &c. These works of MM. Sandberger are full of accurate detail.

stones, more clearly identifying the succession of rocks in these foreign tracts with that in Devonshire. M. Adolf Römer, for example, divides this upper group into the following ascending series:—1. Receptaculite-schists, so called because they are charged with the Receptaculites Neptuni, Defrance; 2. Limestone characterized by Goniatites auris and other species; 3. Schists with many Goniatites, Clymeniæ, and Cypridinæ; 4. and lastly, Schists containing Rhynchonella cuboides and Productus subaculeatus,—beds which are paralleled by that author with the Upper Devonian strata of North Devon. Looking, however, at this Upper Devonian division in a broad point of view, as it generally appears in Germany, it seems to me to be more frequently characterized by the small Crustacean termed Cypridina * serrato-striata, than by any other fossil. Where the calcareous courses thin out, and Clymeniæ and Goniatites, or other characteristic Shells, are not persistent, still the minute Crustacean is almost everywhere present, often ranging through a considerable succession of beds, and giving to them their prevailing zoological character. In each country, however, through which this division ranges, it exhibits some peculiar features, though in most tracts it is chiefly marked by containing Cypridinæ, Clymeniæ, and certain Goniatites. The name, therefore, of 'Cypridinen-Schiefer,' adopted by MM. Sandberger, who have described so many of the organic remains of this remarkable band of rocks, is, I repeat, highly characteristic of it as a whole.

In Nassau, where the upper limestone is, in some places (as near Weilburg), very little removed from the Lower or massive Eifel Limestone, it has only to be followed a short distance eastwards to be seen divided from its neighbour by copious strata of the igneous rock called 'Schaalstein,' formed of cotemporaneous submarine volcanic ejections.

It is along the northern frontier of Westphalia, however, where all the Devonian rocks subside conformably beneath the overlying Carboniferous deposits, that they assume an importance which can be well understood only by inspecting the remarkable Prussian map before spoken of. There, as is well seen in the cuttings of the Bergisch-Mergisch Railroad, the group above the Stringocephalus-limestone exhibits, first, slaty schists with some thin layers of grey and black limestone containing Goniatites retrorsus,—strata which at Nuttlar attain the great thickness of 1000 feet ('Flinz' of von Dechen) as micaceous sandstones, often running into concretionary forms, as seen at the Rauhe Hardt, near Iserlohn. Then appear the reddish schists with Cypridinæ and a nodular limestone which, from the cavities it weathers into, has been called 'Kramenzel-Stein' or 'emmet-stone' †, the greatest thickness of which is about 200 feet.

It is this nodular Kramenzel-Stein, and the associated schists and sandstone, frequently of a reddish colour, which are most charged with Cypridinæ and Clymeniæ, and they give to the upper group its chief character. When most extended, including the schists called 'Flinz,' the group has the dimensions of upwards of 1300 feet. This Upper Devonian, in the form of 'Cypridinen-Schiefer' and 'Clymenien-Kalk,' as before explained, is much developed in Saxony and in the adjacent tracts of Thuringia and Franconia. (See the foregoing Chapter.) The overlying sandy calcareous band with the Spirifer Verneuilii ‡ terminates

* Prof. Rupert Jones has pointed out (Report Brit. Assoc. 1863, Trans. Sect. p. 80) that these so-called 'Cypridinæ' have no claim to the generic name Cypridina, but belong to Entomis &c.

† The cavities are frequently filled with ants' nests; hence this name given by the workmen.

‡ Von Dechen and his associates have used the name given by myself, in honour of my friend de Verneuil, to the Spirifer which abounds in the same stratum in the Boulonnais (see Bull. Soc. Géol. de France, ser. 2. vol. xi. p. 252). It is, however, the Spirifer disjunctus, having been previously so named by Sowerby.

(in ascending order) the Upper Devonian of the Rhine and Belgium, and is distinguished by a separate colour in the Prussian map *.

Palæozoic Rocks of Belgium.—The oldest rocks in Belgium are those of the 'Système Ardoisier' of Omalius d'Halloy, or 'Terrain Ardennais' of Dumont, so called from the great development of those slaty quartzose masses which rise into the lofty and wild hills of the Ardennes †. These rocks, including the local divisions or systems of M. Dumont, called Terrains Devillien, Revinnien, and Salmien, and even the Gedinnien, or base of the 'Terrain Rhénan' of that author, are now considered by M. de Koninck to be of Lower-Silurian age, seeing that they contain only a few imperfect traces of fossils, none of which are of Upper-Silurian characters, and also that these slates and grits are *unconformably* surmounted by the lowest zone of true Devonian rocks.

The triple division of the Devonian rocks of the Rhine, proposed in the first edition of this work, is found by M. de Koninck to be essentially correct and applicable to Belgium, as determined both by superposition and organic remains. The lowest beds, consisting of quartzose conglomerates, and exhibiting imperfect casts only of Rhynchonella and Orthis allied to species of the earliest Devonian age, are followed by schists laden with those fossils which are common in the lowest fossiliferous rocks visible on the banks of the Rhine and its tributary the Ahr. On this point M. de Koninck agrees with the Prussian geologists von Dechen and Ferd. Römer, and with myself, that the so-called Systèmes Coblentzien and Ahrien of Dumont are absolutely one and the same deposit. (See the Table at the end of the Chapter.)

Occurring in Brittany and other parts of France, as will presently be shown, these beds are represented in North Devon by the rock forming the North Foreland and cliffs of Ilfracombe (p. 272); whilst, judging from some of the fossils, M. de Koninck thinks, with us in England, that they have also their equivalents at Hope's Nose and Meadsfoot near Torquay in South Devon, and at Looe and Fowey in Cornwall.

The same group of fossils has, indeed, a very wide range, and has been recognized in the Asturias and other parts of Spain, at Constantinople ‡, and at the Cape of Good Hope, if not in Tasmania. This is the zone which is characterized by the broad-winged Spiriferi Spirifer hystericus and Sp. cultrijugatus, and was well termed 'Spiriferen-Sandstein' by Ferd. Römer. The other principal fossils are Orthis striatula, Schloth., O. Sedgwicki, de Vern., Terebratula Archiaci, de Vern., Chonetes sarcinulata, Hupsch, Pterinea lineata, Goldf., Grammysia Hamiltonensis, de Vern., Homalonotus armatus, Burm., and Pleurodictyum problematicum, Goldf., &c. M. de Koninck enumerates, in short, 23 species which are common to Belgium and the Rhine, many of them being also known in Devonshire; whilst not one of them has been detected in an Upper Silurian rock in any part of the world. Just as in my own Table, the Wissenbach Slates are placed by M. de Koninck at the summit of this Lower Devonian division.

The Middle Devonian of Belgium, or calcareous centre of the series, is de-

* The Prussian geologists have even delineated on their map three divisions in this one group, which in ascending order are:—1. Flinz; 2. Kramenzel-Stein; 3. Verneuilii-Schiefer.

† In the Prussian geological map these slates are also grouped as Devonian.

‡ The fullest proofs that the oldest fossils discovered in the environs of Constantinople (first noticed by Hamilton and Strickland) are of Lower-Devonian age (that is, of the 'Système Rhénan' of Dumont—see his Carte Géologique de l'Europe) is to be found in M. de Verneuil's description of the fossils collected by M. P. de Tchihatcheff to complete his great work on the Bosphorus and Asia Minor (Asie Mineure: Description physique; 4me Partie, Géologie, 1e Partie, 1867). In looking at the beautiful and instructive geological map of those regions which he has explored during so many years, I cannot but suggest that many of the schistose and quasi-crystalline rocks which underlie the Devonian rocks of Asia Minor will prove to be of Silurian age. At the last Meeting of the British Association at Nottingham it gave me sincere satisfaction to dwell upon the high merits of this excellent work.

scribed by M. de Koninck as consisting of several bands. The lowest strata are quartzose, schistose, and calcareous, with partial conglomerates (Burnot), and exhibit few fossils; next, limestone laden with true Eifel fossils, including Phacops latifrons, Bronn, Bronteus flabellifer, Goldf., Cyrtina heteroclyta, Defrance, with Stromatopora, Cyathophyllum, and many other Corals.

A thin course of limestone with Calceola sandalina succeeds, and a suite of fossils which occur in the Devonshire limestones of Plymouth, Newton Bushel, and Chircombe Bridge, and are unknown in France and in the Harz. Among these are Phragmoceras pyriforme, Goldf., Cyrtoceras nodosum, Bronn, Orthoceras nodulosum, Schloth., Acroculia prisca, Goldf., Bellerophon tuberculatus, Féruss., Lucina proavia, Goldf., Streptorhynchus umbraculum, von Buch, Spirifer speciosus, Goldf., Sp. lævicosta, Schloth., Sp. curvatus, Schloth., Rhynchonella primipilaris, von Buch, with two species of Cupressocrinus. This group, according to M. de Koninck, occurs also in China and Australia.

The upper portion of the Middle Devonian consists of the limestone with Stringocephalus Burtini and other well-known fossils, namely Uncites gryphus, Schloth., Megalodon cucullatus, Goldf., Murchisonia bigranulosa, d'Arch., Macrocheilus arculatus, Goldf., and Sphærocrinus geometricus, Goldf. In placing this bed at the summit of the Middle Devonian or Eifelian group, M. de Koninck is in accordance with Ferd. Römer and other Prussian palæontological authorities. In Brabant, as at Soignies and Ecaussines, it reposes upon the Lower Devonian, and is in every respect the equivalent of the limestones of Paffrath, Refrath, Münster-Eifel, and Villmar, in the Rhenish countries. In Devonshire, M. de Koninck identifies with this band the limestones of Bradley, Babbacombe, and Newton Bushel, and compares it with the Marcellus Schists and Hamilton Group of North America.

In following the Devonian rocks from the Rhine towards Belgium, it is found that in their details they differ from those of Westphalia. At Aix-la-Chapelle, where the Belgian type may be said to begin, all the members of the series are much attenuated. We there find a meagre equivalent only of the Lower Devonian,—the calcareous representative of the Eifel being but a poor coralline rock, in parts dolomitic, followed only by certain nodular schists charged with the Receptaculites Neptuni, Defrance, and Spirifer disjunctus, Sow., which alone represent the copious masses of Flinz, Kramenzel-Stein, &c. of the previously mentioned tracts.

The Upper Devonian of Belgium (part of the 'Système Eifélien' and part of the 'Condrusien inférieur,' Dumont) consists at its base of calcareous schist with nodules, and is specially characterized by its abundance of Clymeniæ, Goniatites, and Favosites; besides which, it contains Receptaculites Neptuni, Defr., Davidsonia Verneuilii, de Kon., Avicula Neptuni, Goldf., Orthis Dumonti, de Vern., Rhynchonella cuboides, Sow., Cardium palmatum, Goldf., and Cypridina serratostriata, Sandb.

This band is paralleled with the beds of Budesheim in the Eifel, with the red limestones and iron-beds of Nassau described by Sedgwick and myself*, with the base of the Petherwin group in Cornwall, with the strata of Neuilly (Hérault) in France, and the rocks of Elbersreuth and Schubelhammer in Bavaria, illustrated by Count Münster. It is the Genesee Slate and Tully Limestone of North America, and is considered to have its representative in the 'Domanik-Schiefer' of Keyserling, on the banks of the Uchta in the north-eastern extremity of Russia-in-Europe, whence the fossils range even into Nova Zembla.

* See Trans. Geol. Soc. Lond. ser. 2. vol. vi. p. 250.

The group terminates upwards in a mass of olive and brown schists alternating with calcareous and dolomitic courses, the whole forming the usual borders of the coal-basins of Belgium. This, the highest Devonian group, is characterized by containing Orthis striatula, Schloth., Spirifer disjunctus, Sow. (Sp. Verneuilii, Murch.), Sp. comprimatus, Schloth., Strophomena Dutertrii, de Vern., Productus subaculeatus, Murch., Acervularia pentagona, Goldf., Favosites polymorphus, Goldf., &c.

This is the upper member of the Petherwin group of English geologists, and is represented in North Devon by the sandy rocks of Barnstaple, Pilton, Croyde, Baggy Point, &c. It has been traced by de Koninck in Belgium, at Manche, Rhisme (Namur), Huy, Verviers, Chaufontaine, and Philippeville, and is well seen in the Boulonnais, where it is clearly distinguished from the lowest Carboniferous rocks, by which it is conformably surmounted.

Certain fossils of this age have as wide an extension as those of the underlying divisions of the Devonian rocks, since they have been identified, by Davidson, de Koninck, Salter, &c., from China * and other parts of Asia, and are abundant in Russia and Siberia.

In terminating this sketch of the Devonian rocks of the Rhenish Provinces and Belgium, it may be observed that, notwithstanding a certain similarity in general aspect of the fossils, even the lowest Devonian here indicated is entirely different in its fossil species from the Upper Silurian of any part of Europe; whilst the Middle (or typical) Devonian is still more distinct. Neither of these rocks contains, for example, any Silurian species of Crustacean or Cephalopod; the genera of the central masses are peculiar; and Graptolites, which occur from the bottom to the top of the Silurian rocks, are unknown in any Devonian stratum. The Devonian and Upper Silurian are therefore infinitely more distinguished from each other, as natural-history groups, than the Lower and Upper Silurian, which, on the contrary, are linked together (as proved in the earlier Chapters) by a considerable number of the same species of Crustaceans, Cephalopod and Brachiopod Shells, Corals, and Graptolites.

According to de Verneuil, the Lower Devonian rocks of the Rhine are the equivalent of the Oriskany Sandstone of the United States, as will be explained in a subsequent Chapter. Other analogies have been indicated, by means of their fossils, between these Continental deposits and the Marcellus Slates and Hamilton Group of North America; but, for the present, let us simply bear in mind that, whether we regard the physical order of the masses, or their imbedded remains, the Rhenish and Belgian rocks (which have afforded more than 450 species of fossil animals) are not only really remarkable counterparts to the succession in Devonshire, but, in consequence chiefly of the perseverance and activity of their explorers, have already much outnumbered in fossils their British equivalents.

* The respected Chinese medical missionary, Mr. W. Lockhart, who communicated to the Royal Geographical Society a comprehensive memoir on the great watercourses and on the productions of China, supplied me with Upper-Devonian fossils from the province of Tse-chuen, in the interior of that vast country, which are identical in specific character with Spirifer Verneuilii, Sp. Archiaci, Productus subaculeatus, and other European forms: coal also abounds in that region.

Carboniferous Rocks of the Rhenish Provinces and Belgium.—The upward succession from the Devonian into the Carboniferous deposits is clear on both banks of the Rhine and in Belgium; and if in the latter country certain Lower Carboniferous schists are attenuated, this thinning-out of one portion is more than compensated by the presence of noble masses of Carboniferous Limestone.

The Carboniferous Limestone of Belgium reposes, however, upon the Devonian schists containing Spirifer disjunctus (or Verneuilii), the well-known fossil of the Rhenish-Prussian tracts and the Boulonnais, without any trace of those lower sandstones which are so largely intercalated in Scotland and Ireland (pp. 291 and 294). This Carboniferous Limestone, and a thin overlying sandstone representing the Millstone-grit, form the support of the two great Coal-basins of Liége and Hainault. The numerous repetitions and folds of this rock, as distinguished from the lower or Devonian limestone, are admirably displayed in M. Dumont's map and sections.

During his earlier researches, M. de Koninck was led to believe in the existence of two distinct zones of Carboniferous Limestone, as expressed in the first edition of this work (p. 375), the fossils of the tract near Visé being very different from those of Tournay. He now, however, has come to the conclusion that both these form one natural mass, since, although their respective fossils differ materially, they are closely united by a number of species common to both districts. Illustrating and extending the application of his views, M. de Koninck further suggests that the fossil species of Visé and Tournay are repeated in like manner in several localities of the British Isles respectively; and he traces the same distinction over the Continent to the Ural Mountains on the east, and across the Atlantic to America on the west.

In making these extensive comparisons, M. de Koninck enumerates 53 species as distinctive of the Visé assemblage, and 57 species as characteristic of Tournay; whilst he cites 40 species which are common to both localities. The latter, or the common forms, belong chiefly to the genera Euomphalus, Pleurotomaria, Bellerophon, Productus, Orthis, Athyris, Rhynchonella, with the Trilobite Phillipsia, and palates of Psammodus and other Fishes.

Through the comparisons instituted by this able palæontologist, we learn that many of the same species were so widely spread out during the Carboniferous era as to extend over the northern hemisphere, being here and there collocated in distinctive assemblages, often at great distances from each other,—those parts of the ocean having been specially suitable to their existence.

The splendid rocks of this formation, which the traveller admires as he passes along the railroad from Namur to Liége, gradually thin out as they range towards the Rhine. They make, in short, their last appearance as a solid limestone at Cromford near Ratingen, on the right bank of the Rhine; for in extending thence to the east and north they become almost non-calcareous. Instead of two or more massive divisions, they dwindle into one or two thin, flat beds of black limestone, very similar to the black Culm-stone of Devonshire, which is in that district the feeble representative of the great Carboniferous or Mountain Limestone of other parts of England. Like the Devonshire rocks, the Westphalian strata are characterized by the Posidonomya Becheri, which occurs in Belgium, even where the calcareous matter is entirely absent, as well as in the schists of Herborn and other places, distinctly marking the centre of the Lower Carboniferous rocks.

In the Rhenish Provinces the lower member (the schists below the limestone) is usually very siliceous, and is in that tract the 'Kiesel-Schiefer' of the

Prussian geologists, which occasionally expands into a deposit of considerable dimensions. The limestone which reposes on these schists and sandstones is again surmounted by a copious succession of sandstone, mineralogically not very unlike many of the lower divisions of the so-called 'Grauwacké,' and formerly known under the name of 'Flötz-leerer Sandstein.' Professor Sedgwick and myself showed that, while the Posidonomya-beds represented the 'Culm' or true Carboniferous Limestone, this 'Flötz-leerer Sandstein' or 'Jüngste Grauwacke' was simply the equivalent of our British Millstone-grit, and that, as in England, it lay immediately beneath the most productive Coal-measures.

This identification was, in truth, one of the most satisfactory assurances that a knowledge of organic remains, combined with a clear view of the order of superposition, had led us to a correct inference in placing as a member of the Carboniferous deposits strata which had previously been connected with much more ancient rocks.

Having thus briefly indicated the character of the rocks which form the immediate support of the Upper or productive Carboniferous strata of Westphalia and Belgium, it is not my object to attempt any detailed description of the Coal-measures properly so called. In Westphalia these Coal-beds plunge under the Cretaceous rocks upon the east; and in Belgium (as, for example, at Liége) they are at once surmounted by Tertiary deposits. (See Dumont's Maps.)

Whilst the Devonian rocks of the Rhine, unlike those of Saalfeld (p. 386), have afforded few traces of Land Plants, it is important to observe that it is specially in this Lower Carboniferous group that nearly all the so-called 'transition' and 'grauwacké' phytolites described by various German authors have been collected. Seeing that this series, in the Rhenish Provinces, is so very analogous to that of Britain, geologists will indeed be interested in comparing the Plants described by Göppert, Unger, and others with the rich flora of the same age found in Northumberland *, Scotland, and parts of Ireland.

Although not adopted by the Prussian geologists in the great map of the Rhine Provinces, it is right to mention the opinion of M. R. Ludwig †, that the quartzites above Nauheim, which seem to be an eastern prolongation of the Taunus Mountains, and repose unconformably upon certain Devonian rocks, are (judging from their mode of bedding and mineral character, and, above all, from the large Land Plants they contain) equivalents of one of the oldest members of the Carboniferous series. On this point I cannot pretend to express a decided opinion without a more elaborate examination than I have yet given to the tract. M. von Dechen does not adopt this view.

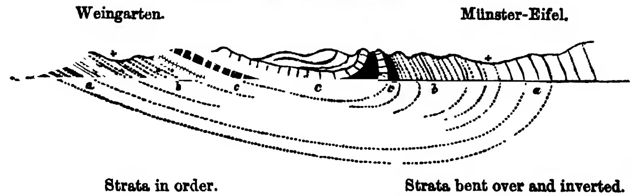
Inversions.—Inadequate as the preceding brief sketch may be in con-

* See remarks, by Mr. G. Tate, on the Fossil Flora of the Coal-formation, in the 'Natural History of the Eastern Borders,' by Dr. Johnston: 1853.

† See 'Rheinische Schiefer-Gebirge,' with a map: Jahrbuch der Vereins für Naturkunde in Herzogthum Nassau, (Wiesbaden) 1853.

veying a just idea of the nature and contents of the older deposits of this interesting region, it would be still more imperfect if a reference, however cursory, were not made to the phenomenon of the inversion of some of its stratified rocks. Adopting M. Dumont's explanation of such reversals of the normal order in Belgium, Professor Sedgwick and myself applied it to account for the position of certain masses of the Eifel country. We pointed out how, near Münster-Eifel, the overturning of the beds had been produced by movements which acted throughout masses of sediment several thousand feet in thickness. The phenomenon is illustrated by this diagram †.

INVERSION IN THE EIFEL EXPLAINED.



c. Eifel Limestone and Shale.
a, b. Shelly Devonian greywackè.

In this case, whether by following the strata upon their strike, or by making a short traverse across them, as in the preceding section, the true order was soon detected.

Again, on the northern or outer frontier of the Devonian rocks of Westphalia, where the order is very regular, all such strata being seen to plunge under the Carboniferous beds, as before explained, the attention of the observer is roused when, exploring north-westwards to Brilon, he finds a large tract of country (much penetrated by very ancient igneous rocks) towards Berleburg, exhibiting everywhere the older beds overlying the younger. This phenomenon, long ago known to the Prussian geologists von Dechen and Erbreich, is expressed in this woodcut, taken from part of a larger section published by my colleague and myself in the Geological Transactions ‡.

INVERTED STRATA SOUTH OF BRILON.

c. Lower Carboniferous schists (Kiesel-Schiefer and Posidonomyen-Schiefer).
b. Upper Devonian schist, limestone, and iron-ore } Devonian.
a. Slaty Devonian rocks................................ }
* Bands of igneous rocks.

† From Trans. Geol. Soc. ser. 2. vol. vi. p. 277.
‡ See Sedgwick and Murchison, Trans. Geol. Soc. Lond. ser. 2. vol. vi. p. 239. The woodcut in the Geological Transactions shows the Coal-strata to the north covered by Cretaceous rocks.

The reader will see that the Lower Carboniferous rocks (*c*), consisting of the 'Kiesel-' and 'Posidonomyen-Schiefer,' which in their true positions are overlying, here dip under the Upper or calcareous Devonian group, *b*; whilst the last have been carried under still older members of that series (*a*), or the slaty 'Grauwacké' of this region. Nay, more, he perceives that igneous rocks (porphyries, greenstones, &c.), formed in part successively on the bottom of the same seas in which the Devonian strata (*b*) were accumulated, have also been overthrown *en masse* with all the other rocks. It follows, therefore, that the regular order in which these formations are traceable along so wide an adjacent region is here completely deranged, and that all the rocks are inverted, the older being incumbent on the younger! Now, this very same phenomenon of the overturning of huge masses of the solid crust of the earth has not had its limit in the Rhenish Provinces, but has extended into Belgium, where the same strata, as described by M. Dumont, are affected along a band having precisely the same strike as those great folds in Westphalia and the Eifel*. They are therefore to be regarded as great parallel wave-like undulations, similar to those of the United States which have been theoretically explained by the Professors Rogers.

In looking back to p. 145, we see indeed that, in Cornwall, this great European inversion has proceeded much further to the west, and that masses of an antiquity unknown in the Rhenish Provinces and Belgium (*i. e.* the Lower Silurian) there overlie Devonian strata. In that example, both the rocks being fossiliferous, no doubt as to the intensity of the overthrow can exist.

It may also be remarked that in one district of Thuringia certain Plant-beds which belong to the Lower Carboniferous division plunge under Upper Devonian beds charged with Cypridinæ and Clymeniæ, and that near Ober-Steinach, in Meiningen, these Devonian strata are likewise apparently surmounted by true Lower Silurian!

If a young geologist had detected for the first time such abnormal relations in a country like the Eifel, where, besides igneous eruptions of remote periods similar to those in the last diagram, the strata have been pierced by volcanos which have certainly been in activity under the atmosphere, he might suppose that the latter, with their craters and coulées, must have been associated with some influence analogous to that which produced the inversions; but examination dispels such an hypothesis; for we see that these subaërial volcanos, with their scoriæ, pumice, lava, and ashes, are nothing more than superficial pustules, which, in bursting forth, and spending their energies, produced no sort of alteration in the position or nature of the rock-masses. They merely vomited their contents into depressions already prepared to receive them, thus showing us that when they appeared the present system of hills and valleys had been completed.

* See the very remarkable geological map of all the volcanic tracts in the Rhenish Provinces, by C. von Oeynhausen.

TABLE OF THE UPPER PALÆOZOIC ROCKS IN EUROPE, FROM THE SUMMIT OF THE SILURIAN TO THE PERMIAN INCLUSIVE.

Groups.	Divisions.	Subdivisions.	Characteristic Fossils.	British Localities.	Foreign Localities.	Remarks.
CARBONIFERIAN.	UPPER.	Red Sand and Marl (England). Marl, Sand, and Conglomerate (Perm). (Sand-Schiefer or Lower Bunter, Germany.)	VERTEBRATA.—Rhopalodon Mantelli, R. Murchisoni, R. Wangenheimi. PLANTS.—Calamites arenaceus, Neuropteris salicifolia, Odontopteris Strogonovii, O. Permiensis, Pecopteris Gœpperti, Sphenopteris lobata, S. erosa, Nœggerathia, Lepidodendron elongatum.	West of Doncaster; St. Bee's Head and Corby Castle, Cumberland. (In England generally a partial red capping only of the Magnesian Limestone.)	*Russia.*—Governments of Perm, Orenburg, and Kazan. *Germany.*—Flanks of the Thüringerwald and the Harz; environs of Gera; Altmorschen, Hesse.	See 'Russia-in-Europe for places where conglomerates &c. with copper Rhopalodon, and Plant *overlie* and *interlace* Zechstein.
	MIDDLE.	Magnesian Limestone (England). (Zechstein, Germany.)	VERTEBRATA.—Zygosaurus lucius, Platysomus striatus, Palæoniscus longissimus, P. varians. INVERTEBRATA.—Terebratula elongata, T. Geinitziana, Spirifer alatus, Camarophoria Schlotheimii, Productus horridus, Strophalosia Goldfussii, Athyris pectinifera, Pecten pusillus, Monotis speluncaria, Bakewellia antiqua, Byssoarca striata, Schizodus dubius, Turbo helicinus, Pleurotomaria antrina, Nautilus Frieslebeni, [illegible]	Coast cliffs from Tynemouth to Hartlepool, Clacksheugh, Eldon, Thickley, Ferry Hill, Humbleton Hill (Durham); Masham, Roach Abbey, Bramham Moor, Ferrybridge, Tadcaster, Knaresborough, Bolsover Moor, Cuswell Crags, and Steetly (Yorkshire, [illegible]	*Russia.*—Pinega, Ust Vaga to Archangel, Kiriloff, Kazan to Perm, Sergiefsk, Rivers Kidash and Dioma: abounds in Perm and Orenburg. *Germany.*—Flanks of Thüringerwald and Harz; East flank of [illegible]	In Russia, limestone containing the Shells o Germany and England alternate with copper-bearing sands, marls, rock-salt, &c. The Plants of these [illegible]
		[illegible] Millstone-grit (England). Moor-rock (Scotland). (Flötzleerer Sandstein, Germany.)	reticulatus, Aviculopecten arenosus, A. scalaris, A. papyraceus, Goniatites reticulatus, G. spiralis, Fenestella, Lingula mytiloides. PLANTS.—Lepidodendron elegans, Stigmaria, Calamites.	England; West and North Ridings, Yorkshire; Culm-trough of North Devon; part of the Scotch coal-fields, Kilkenny, Clare, and other parts of Ireland.	*Germany.*—Harz and Rhenish Provinces of Prussia, edges of coal-fields of Dortmund and Saarbrück. *Belgium.*—Chokier, Ampsin, pits near Mons.	this age. Some coal beds occur in Yorkshire and Lancashire.
		. . . .	VERTEBRATA.—Ctenacanthus major. Orodus ramosus, Psammodus porosus, Cochliodus magnus, C. contortus, Helodus turgidus, H. lævissimus, Pœcilodus transversus, Cladodus, &c.	*England.*—Margin of the South-Welsh coal-basin; Derbyshire, Flintshire, Pennine Chain, West and North Ridings of Yorkshire, Northumberland.	*Russia.*—Valdai Hills; Moscow; Tula; Kaluga; Donetz Coal-field; banks of the Volga below Kazan; Archangel; flanks of the Ural Mountains; West of Cracow.	. . . .
	MIDDLE.	Carboniferous or Mountain Limestone. (Berg-Kalk. Calcaire Carbonifère.)	INVERTEBRATA.—Spirifer striatus, Sp. lineatus, Sp. glaber, Terebratula sacculus, Orthis resupinata, Conocardium aliforme, Euomphalus pentangulatus, Bellerophon apertus, B. cornu-arietis, &c., Orthoceras laterale, O. giganteum, Nautilus carinifer, Phillipsia Eichwaldi, P. Brongniarti, Griffithides globiceps, Brachymetopus Ouralicus, Lithostrotion junceum, L. basaltiforme, Lonsdaleia floriformis, Platycrinus, Poteriocrinus, Rhodocrinus, Actinocrinus. PLANTS.—Few; chiefly Lepidodendron, Ulodendron, Stern-	*Scotland.*—Ayrshire and the counties of Renfrew, Lanark, Linlithgow, Fife, Edinburgh, and Haddington. *Ireland.*—Abounds from Fermanagh and Tyrone in the north through the central counties to Cork in the south.	*Germany.*—Hof, Bavaria; Grund, Harz; Ratingen, Westphalia; Hainichen and Ebersdorf, Saxony. *Belgium.*—Visé, Tournay, Namur, Theux, Dinant, Soignies. *France.* — Sablé, Juigné, Bazonge, Fercé, &c. *Spain.*—Picos de Europa, Astu-	Important coal-seams in Scotland are subordinate to the limestone of this division. In Saxony Prof. Geinitz distinguishes the Plants from those of the Upper Coal.

Infinitely more intense, therefore, must have been that much more deeply seated agency which, giving rise to such internal writhings of the earth, inverted thousands of feet of strata over vast areas, and, in some tracts bending them like reams of paper, placed them abruptly in others over deposits formed at immeasurably subsequent periods. Striking, however, as are the above-mentioned features of inversion, still grander examples will be adverted to in the last Chapter.

After all, such phenomena are only local exceptions, as respects the surface of the globe, on which, fortunately, the original impress of order is visible over very large regions. Reverting, then, to such order, I annex the accompanying Table of the natural divisions of the Devonian and Carboniferous rocks of the Continent as compared with their equivalents in the British Isles, the whole surmounted by the Permian rocks described in the Thirteenth Chapter. In this Table, the student sees at one glance the whole of the Upper Palæozoic succession,—the Silurian System comprising the larger portion of the Lower Palæozoic rocks. The Table is substituted for one on a more limited scale given in the first edition of this work, relating to the tracts described in this Chapter only, and which was prepared chiefly to show both the triple subdivision of the Devonian rocks, and also that not one of those groups, as based upon the distribution of former life, is in unison with the lithological groups and systems of the late M. Dumont*. That eminent geologist, who had so admirably reduced to order the complicated and often inverted strata of his native country around Liége, undervaluing the weight of fossil evidence, proposed a classification based solely upon the mineral character of each succeeding mass. Such a division, being found to be inconsistent with the great principle of modern geology (strata identified by their organic remains), is no longer adverted to, and the Table now laid before the reader, though still susceptible of improvement, will, I trust, be found applicable to wide areas of the earth's surface.

* See 'Siluria,' 1st ed. p. 331.

CHAPTER XVII.

SILURIAN AND OVERLYING PALÆOZOIC ROCKS OF FRANCE, SPAIN, PORTUGAL, AND SARDINIA.

ALTHOUGH the Palæozoic rocks (often, however, in a metamorphic state) occupy considerable areas in France, it is not possible, on this occasion, to offer more than a slight sketch of their features, even in the tracts where they are clearly exhibited. They are largely developed in Brittany; and there the authors of that great work the Geological Map of France * divide them into two principal masses,—the inferior being composed of glossy schists (schistes satinés luisans) of great thickness, in which a few thin courses of grit and shaly limestone occur. In their mineral aspect, and in their entire want of fossils, these strata remind the geologist of the rocks which underlie the lowest fossiliferous deposits of Bohemia; and they may not unaptly be compared with some of the crystalline and sub-crystalline rocks of Anglesea and the Longmynd, or hardest Cambrian rocks of the Welsh and English series. Their mean direction in Brittany is, like that of the Longmynd in Shropshire, from east 20° north, to west 20° south; and they were, indeed, long ago termed 'Cambrian' by Élie de Beaumont and Dufrénoy.

Under the name of 'Silurian' these eminent authors included a thick and complex series of fossiliferous strata, which they again divided into two groups. The lowest of these they thus arrange:—1st, conglomerates and siliceous sandstones; 2nd, bluish schists, which at Angers, Poligny, &c. furnish good slates, and correspond, by their fossils, to the Llandeilo formation of Britain,—Trinuclei and Ogygiæ, with Illænus giganteus &c., being abundant. So far the succession in Brittany, as dependent on organic remains, is in unison with that of Britain; but the chief portion of the next division, consisting of compact limestones and schists, has been abstracted by de Verneuil from the Silurian, and shown to belong to the Devonian system. In this way, the order in Brittany is analogous to that of Cornwall and many parts of Germany, in which tracts there is, as already shown, an equally sudden succession from Lower Silurian to Devonian.

The second group adopted by the authors of the Geological Map of France is made up, first, of siliceous conglomerates, coarse grits, and argillaceous schists, which old geologists would have termed 'greywackè,' then of beds with coal, and, lastly, of a limestone specially characterized by

* MM. Élie de Beaumont and Dufrénoy. Their 'Explication de la Carte Géologique de France,' 2 vols. 4to, is a rich storehouse of valuable observations.

the presence of Amplexus and Productus. Now, d'Archiac and de Verneuil have demonstrated that this highest group is neither Silurian nor Devonian, but a true member of the Carboniferous rocks. It is, in its fossils, identical with the Carboniferous Limestone of many regions.

All these fossiliferous deposits, whether Lower Silurian, Devonian, or Lower Carboniferous, are conformably arranged, whatever may be the inclination of the beds; and, striking from east 15° south to west 15° north, they overlap transgressively the older unfossiliferous rocks on which they repose. It was the accordance in their direction and inclination which naturally led Élie de Beaumont and Dufrénoy to include, in the first instance, all these fossiliferous deposits in one period. But in the interval which has elapsed since that classification was proposed, Brittany has been examined by many geologists, including Frappoli, de Fourcy, Durocher, Blavier, and Rouault, as well as by de Verneuil and d'Archiac, all of whom agree in adopting the order and nomenclature here followed. The eastern limits of the province, towards the Departments of La Mayenne and La Sarthe, have indeed been studied in the greatest detail by M. Triger, to whom the execution of the geological map of the last-mentioned district was confided. The collection of fossils made from the Palæozoic rocks around Cherbourg by my old and indefatigable correspondent, the late M. de Gerville, has also contributed essentially to clear away the difficulties attending a right classification; and, lastly, the Geological Society of France (during its meeting at Le Mans, 1850), under the leadership of M. Triger, made a section across the older rocks to the north of Angers, the *résumé* of which was published by de Verneuil and de Lorière *.

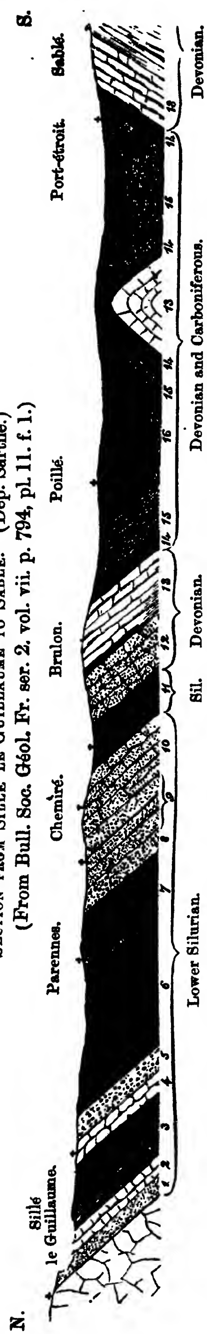
The following diagram (p. 408), reduced from their publication, exhibits the principal geological features of the country between Sillé le Guillaume and Sablé, a distance of about twenty-five English miles, and clearly developes a succession of the Palæozoic formations from the Lower Silurian to the Carboniferous rocks inclusive.

In this section, the lowest stratum is a white sandstone (1), resting on a porphyry with large red and white crystals. The still more ancient crystalline and glossy schists of Brittany are here wanting; whilst the lowest visible beds (1 to 6), in which some limestone appears, have not yet afforded any fossils to serve as equivalents to those of the 'Primordial Zone' of Bohemia and Scandinavia, or the Lingula-flags of Britain.

Such was our knowledge when the last edition of this work appeared; but since then some traces of what has been referred to the 'Primordial' Silurian fauna in France have been detected. Near St. Leonhard des Bois (Sarthe), MM. Triger and de Verneuil have discovered, under a mass of roofing-slates containing the Asaphus and Illænus of Llandeilo age, beds of quartzose sandstone, one of which was loaded with Lingulæ and Bilobites, and they think it may be the equivalent of the Lingula-flags. M. Dalimier also regards the

* In a recent excursion, MM. Triger, Daubrée, and de Verneuil discovered that this section is not so simple as it appeared to be in a former examination; but the foldings of the strata do not affect the general order of succession here given.

SECTION FROM SILLÉ LE GUILLAUME TO SABLÉ. (Dép. Sarthe.)
(From Bull. Soc. Géol. Fr. ser. 2. vol. vii. p. 794, pl. 11. f. 1.)



Carbo-niferous. { 16. Anthracitic schists, &c. Poillé, La Bazouge, &c. 15. Carboniferous Limestone, with Productus gigas, Chonetes camoides, &c. 14. Sandstone, schist, and anthracite (worked at Sablé),—base of the Carboniferous group.

Devonian. { 13. Schists and limestones with Devonian fossils. 12. Whitish sandstone containing Dalmania calliteles, Homalonotus Gervillei, and other Devonian fossils.

Lower Silurian. { 11. Ampelite-schists, with Cardiola interrupta, Orthoceras pelagicum, Trilobites, and Graptolites, showing a trace of the Upper Silurian base. 10. Ferriferous grit and sandstone (with Placoparia Tournemini) like that of May in Normandy. 9. Sandstone and schist with several courses of ampelite charged with Graptolites. 8. Conglomerate of white quartz-pebbles with some Trilobites and Graptolites. 7. Roofing-slates of Parennes, with Calymene Tristani. 6. Clay-slate &c. 5. Thin band of conglomerate in a matrix of talc-schist. 4. Magnesian limestone, passing into true dolomite. 3. Argillaceous schist or clay-slate. 2. Siliceous limestone, slightly magnesian, without fossils, and intercalated in schists. 1. Whitish felspathic grit or arkose (bottom-rock of the section).

sandstones with Bilobites and Scolithus as equivalent to the same beds (Bull. Soc. Géol. ser. 2. vol. xx. p. 126). It may, however, be suggested that these beds rather represent the upper portion of the Primordial Zone, containing the same fossils as the quartzose rocks of the Stiper Stones, which, like those of France, directly underlie the Llandeilo formation.

The great schistose and slaty mass which follows (Ardoises de Parennes, No. 7 of the diagram) forms the inferior limit of Silurian life as known in France. From its wide extension and its fossils, this formation (the Angers Slates) merits great attention; for it is doubtless, as M. de Verneuil states, the representative of the Llandeilo rocks of Britain, of Barrande's 'Second Zone' in Bohemia, and of the Orthoceratite-limestones of Scandinavia, Russia, and North America. It is, in fact, the dominant member of the rocks termed Lower Silurian by all the authors who have described them in those countries.

The slaty masses of Brittany are characterized, like their equivalents elsewhere, by a profusion of Trilobites. Unfortunately these Crustaceans are, for the most part, much flattened and distorted; but the following species have been recognized; and some of them were long ago figured by Guettard and Brongniart * :—

Calymene Tristani, Brong.; C. Arago, Rouault; C. Verneuili, Rouault; Asaphus Guettardi, Brong.; Ogygia Desmaresti, Brong.; Illænus giganteus, Burm. (the last two are gigantic species); Ill. Beaumonti, Rou-

* Crustacés Fossiles: Paris, 1822.

ault; Acidaspis Buchii, Barr.; Phacops (Dalmania) socialis, Barr.; P. Dujardini, Rouault; Placoparia Tournemini, Rouault; Cheirurus claviger, Beyr.; Lichas Heberti, Rouault; Trinucleus Pongerardi, Rouault *, &c.

Mollusks are scarcer than Trilobites; the well-known British species Bellerophon bilobatus, however, is not unfrequent; but, as a rule, few of the species of Crustacea or of Shells are the same as those of Britain, while many are identical with the fossils of this age in Spain and Bohemia.

These Lower Silurian schists, in which also are Graptolites, occupy an extensive tract (as may be seen by referring to the geological map of France), and crop out south of the harbour of Brest in the Bay of Crozon, where de Verneuil has detected in them the Calymene Tristani. The deposit affords the best roofing-slates at Angers, where the quarries are 300 to 400 feet deep. There the lines of original deposit and the laminæ of cleavage coincide. In fact, the remains of the included Trilobites occur along the division by which the highly inclined slates are cleaved—a phenomenon rarely observed in Britain, where the cleavage is usually oblique to the bedding. (See p. 32.)

The peninsula of the Cotentin also contains these Trilobite-schists, near Siouville, and in that tract the late M. de Gerville collected their fossils, including Calymene Tristani.

That species and Placoparia Tournemini have recently been found on the Hill of le Roule near Cherbourg, in slates underlying the hard siliceous sandstones largely employed in the construction of the great breakwater of that port—rocks which, according to de Verneuil †, are the exact equivalents of the Caradoc Sandstone in age as well as in lithological structure.

M. Dalimier, on the contrary, who has written several good papers on the Silurian rocks of Normandy and Brittany, considers the hard sandstones of the Roule to be older than the slates with Calymene Tristani, on account of the Scolithus he found in them. The apparent infraposition of the slates he explains by an overthrow or reversal of the beds. The following succession of the older deposits in Brittany, as admitted by Dalimier ‡, is indeed perfectly in accordance with the section by Triger and de Verneuil we have just given:—

Lower Devonian...	Limestone and fossiliferous greywackè (Izé, Gahard).
Upper Silurian. (Trace of lowest part only.)	Slates with Cardiola interrupta.
Middle Silurian. (Lower Silurian, Murchison.)	*a.* Sandstones with the fauna of May (Gahard, May). *b.* Slates with Graptolithus colonus (Mortain, Poligné). *c.* White sandstone without fossils. *d.* Roofing-slates with Calymene Tristani (Angers, St. Leonhard, Cherbourg).
Lower Silurian. ('Primordial' Silurian, Murchison.)	White sandstone with Scolithus, Bilobites, and Lingulæ (=Stiper Stones and Lingula-flags). Red slates and conglomerates.
Cambrian	Green slates and sandstones. Gneiss.

The lower slaty rocks of Llandeilo age are likewise succeeded in La Sarthe by an arenaceous group, represented by Nos. 8 and 9 of the previous woodcut.

* De Verneuil and Rouault, Bull. Soc. Géol. Fr. 2nd ser. vol. iv. p. 320.

† Bull. Soc. Géol. Fr. 2nd ser. vol. xiii. p. 303.

‡ Ibid. vol. xx. p. 126.

It is to be understood that the 'Middle Silurian' of M. Dalimier's Table does not represent the Llandovery rocks. It is simply a natural Lower Silurian or Caradoc and Llandeilo group, the lowest part of which (*d*) is, as before shown, the unmistakeable equivalent of the Llandeilo Flags.

In general, this division exhibits, in ascending order, conglomerates, white and reddish siliceous sandstones, with some subordinate ampelitic schists containing Graptolites, chiefly G. colonus and G. testis of Barrande. The position of these beds is probably the same as that of the Graptolite-schists of Dalecarlia and parts of Sweden. They agree also, according to de Verneuil, with the great schistose member of the American Silurians called the 'Hudson-river Group,' which is equally characterized by Graptolites, and overlies the Trenton Limestone or Llandeilo Flags, the equivalents, as above said, of the Angers Slates. As to the siliceous sandstones wherein the schists are enveloped, they are identical with the rocks of Jurques, Gahard, and May in Normandy, placed by French geologists without hesitation on the parallel of the Caradoc Sandstone of Britain.

In some districts the sandstone is so ferruginous as to be the seat of iron-mines, and the ore in parts is of an oolitic structure: Trilobites are found in it.

The sandstones of May, Jurques, Gahard, &c. are not rich in fossils; but, where I have examined them in company with M. de Verneuil, they contain the British species Bellerophon bilobatus, with Conularia pyramidata, some species of Dalmania, Homalonotus Brongniarti, and H. (Plesiocoma) rarus; the last-mentioned fossil occurs also in the Lower Silurian of Bohemia and Spain.

Like the lower and larger portion of the Caradoc formation in Britain, with which the Bala rocks were identified, this group of sandstones and schists is also connected by its fossils with the inferior slates.

Overlying the above-mentioned strata, there is in France an upper course of ampelite-schist, which, though often confounded with the lower, must be separated from it. These upper ampelitic schists (11 of the section), being black and occasionally bituminous, have, as usual, given rise to expensive and futile searches after coal, especially at St.-Sauveur-le-Vicomte (Manche), Feuguerolles near Caen, and St.-Jean-sur-Ervein the Department of la Sarthe. They are distinguishable from the inferior masses by containing concretions of black limestone with a brilliant fracture, and by certain imbedded fossils. The most characteristic remains are Graptolithus priodon, with some Orthocerata, including Orthoceras pelagicum, O. gregarium, and the Cardiola interrupta *. As this last-mentioned species is chiefly an Upper-Silurian fossil in Britain, and occurs in Bohemia at the base of that division, it might seem fair, in the first instance, to regard this French deposit as of like age. At the same time we must observe that Cardiola interrupta, on the presence of which the comparison was drawn, is occasionally, though rarely, found in the Lower Silurian both of Britain and Bohemia. Whilst, therefore, this zone is clearly recognized through extensive districts of France as the highest of the rocks which are referable to the Silurian epoch, it is by no means an equivalent of the great British formations of Wenlock and Ludlow. We must, indeed, recollect that in Britain, as in Bohemia and Sweden, such schists with Cardiola interrupta and Graptolites underlie limestones with the well-known fossils of Wenlock, Dudley, and Gothland.

In France, therefore, the ascending series of strata is very different from that of Britain. The Upper Silurian, as a whole, is wanting,—the succession being analogous to that of parts of Russia and Germany, where the Lower Silurian is succeeded by Devonian rocks. (See Chapters XIV., XV., XVI.)

Devonian Rocks.—France is by no means poor in Devonian equivalents. Numerous species of fossils derived from the strata 12 and 13 of the foregoing diagram, p. 408,

* See an account of the extension of this zone of ampelite-schists and its intercalated minerals, by M. de Boblaye, Bull. Soc. Géol. France, 1st ser. vol. x. p. 227.

have been compared by de Verneuil with those of the lower shelly grauwacké of the Rhine and the limestone of the Eifel; and he has found that many of them are identical. Among these, the broad-winged Spirifer macropterus, Terebratula Archiaci, Grammysia Hamiltonensis, and Pleurodictyum problematicum are striking Devonian forms, unknown in any Upper Silurian rocks. The great number of species common to the limestones of La Sarthe *, and Nehou † in Normandy, and the lower fossiliferous band of the Rhine naturally leads to the belief that the French and Prussian formations are cotemporaneous. If this view be adopted, we must presume that France possesses no proper and full equivalent of the English Middle Devonian limestone, but simply the inferior portion of the group, called by Dumont the 'Système Rhénan,' and the upper member as seen in the Boulonnais.

Having established the connexion between the Devonian rocks of the West of France and the lower portion of the group in the Rhenish Provinces, de Verneuil observes that in such a consecutive development we might expect to meet with some species which on the continent of Europe and the British Isles are considered to be Silurian; and such is the case. Thus Bronteus Brongniarti, Acroculia robusta, Terebratula eucharis, T. Haidingeri, Atrypa reticularis, Orthis Gervillei, Leptæna Bouei, L. Bohemica, and L. Phillipsi are found in the Devonian of France, and also in the uppermost Silurian of Bohemia. At the same time, Pentamerus galeatus, Atrypa reticularis, with the Corals Heliolites interstinctus, H. Murchisoni, Favosites fibrosus, and Chonophyllum perfoliatum, are common to the Upper Silurian of England or Sweden and the Lower Devonian of France.

The Devonian group of Brittany and the West of France is also usually curtailed, like the Silurian, of its superior members—those which, in the Rhenish Provinces, are so fully developed between the above-mentioned rocks and the base of the Carboniferous system. There are, however, some exceptions. Recent researches have proved the existence of Upper Devonian in the vicinity of the anthracitic band of the Basse Loire, at a place called Copchoux. A young geologist, M. Bureau, has discovered there, in lumps of limestone, Rhynchonella cuboides, Rh. pugnus, Spirifer glaber, &c. ‡

In the 'Bas Boulonnais' also we meet with a fair representative of the Upper Devonian, rich in fossils, on which in 1840 § I published a short memoir. It is there immediately overlain by the Carboniferous Limestone; and both of the formations extend into Belgium and the Rhenish Provinces, occupying the same relative position ‖. This Upper Devonian is everywhere recognized by the abundance of its Spirifers, among which Sp. disjunctus, Sow. (Sp. Verneuilii, Murch.), and its numerous varieties are the most characteristic. Productus subaculeatus and Athyris concentrica are also frequently found. The limestone recurs in different bands with dolomites, sandstone, and schist, composing a

* De Verneuil and Rouault, *ante*, p. 407.

† At this locality abundance of Devonian fossils were obtained by the late M. de Gerville, and distributed among his friends. Both Trilobites and Shells are found there; and among the latter are the common Devonian species Cyrtina heteroclita, Athyris concentrica, and Calceola sandalina. More than 45 species of Brachiopoda were found here by Mr. Davidson.

‡ Bull. Soc. Géol. de France, ser. 2. vol. xviii. p. 37.

§ At that time the exact relations of the strata had not been determined, and I was deceived as to the nature of a small imperfect body, probably a Polyzoan, which was taken for a Graptolite (Bull. Soc. Géol. France, vol. xi. p. 229). M. Dusouich, who has published a good geological map of the Département du Pas de Calais, and M. Delanoue, who gave a small map of the Bas Boulonnais, have ascertained by sinkings that the Devonian deposits range underground towards Béthune and Arras (Bull. Soc. Géol. Fr. 2nd ser. vol. ix. p. 399).

‖ Mr. Godwin-Austen, whose labours have thrown so much light on the real nature of the limestones of Devonshire, has surveyed this district of the Boulonnais in detail, and has endeavoured to show that its lowest strata (limestones, dolomite, &c.) represent the rocks of the Eifel, and are charged with the same species of Corals, and many of the same Mollusks, which are so well known in Devonshire and on the Continent. His section does not exhibit any representative of the Spirifer-Sandstone or Lower Devonian of the Rhine; but the rest of the Devonian rocks of the Rhine and Belgium have, according to his view, their equivalents in the North of France (Quart. Journ. Geol. Soc. vol. ix. p. 231). This view, however, is not adopted by de Verneuil, de Koninck, and others, who continue to view the chief masses of the Boulonnais as Upper Devonian.

group which has its full equivalent, as already shown, in Belgium and on the Rhine. Like the Lower Devonian of Brittany, the rocks in the Bas Boulonnais have a strike from the west-north-west to east-south-east, but are soon overlapped, first by the Carboniferous, and then by the Cretaceous and younger deposits.

Though the Devonian rocks of France are of no great vertical dimensions, and not comparable in thickness to the deposits of like age in Scotland, England, or the Rhenish Provinces, they are of considerable economic importance, particularly in certain schistose and arenaceous districts which they traverse, and where their limestone is much used in agriculture. At the extremity of the peninsula of Brittany these rocks appear in the Bay of Brest.

Carboniferous Rocks of France.—In this work it is impossible to convey an adequate idea of the Carboniferous group, particularly that portion of it which is developed in all the coal-fields of France. The following few observations relate therefore only to the lower and calcareous member which immediately succeeds to the subjacent rocks,—the great Coal-fields of Valenciennes in the north, and those of St. Etienne and Autun in the south, being consequently unnoticed. In the Bas Boulonnais, as before observed, no gap or omission exists in this portion of the series; for the Upper Devonian is at once followed by a thin patch of Carboniferous Limestone, with its large Producti.

Mr. Godwin-Austen has dwelt upon the passage upwards of the Devonian rocks of the North of France into these Lower Carboniferous limestone and interstratified seams of coal, and has made an ingenious theoretical suggestion as to the probable extension westwards of the Coal-field of Valenciennes, so that a workable coal may possibly be found beneath the Tertiary and Cretaceous deposits of the London Basin and the south-east of England*.

I took leave in the last edition of this work to dissent from this view, and have recently expressed the same opinion at the Nottingham Meeting of the British Association. My reasons for this unbelief are as follows:—In its extension below the Cretaceous rocks towards the Straits of Dover, the Coal-field of Valenciennes thins out and deteriorates so much that to the west of Béthune it has become merely a narrow wedge. Next, in approaching the Channel this poor narrow zone is flanked to the north and the south by Devonian rocks lying at once beneath the Chalk (as proved by numerous borings), to the total exclusion of Coal-beds. These data have been all laid down in a 'Carte Industrielle du Bassin houiller du Nord de la France,' prepared upon the Government Map for the Compagnie de Vicogne, showing the numerous fruitless trials of speculators who obtained 'concessions' to search for coal, and only met with subjacent older limestones. With the exception, indeed, of the small patch of Carboniferous Limestone and a very little poor coal at Hardinghen, the Devonian limestones form exclusively the fundamental rocks of the Boulonnais, where they are covered at once by Jurassic or Cretaceous rocks forming the coast-cliffs. My belief therefore is, that, if the Secondary or Tertiary rocks on the English side of the Channel were pierced, the same rocks would in all probability be found as in the opposite part of France, and that either unproductive Carboniferous Limestone, or much more probably Devonian rocks would be met with. The boring for water undertaken at Harwich in the year 1857 has indeed demonstrated that the great productive Belgian coal-field has no extension in the East of England; for after passing through 1030 feet of Tertiary and Cretaceous rocks, a slaty impure limestone charged with Posidonomyæ of the lowest

* See Quart. Journ. Geol. Soc. Lond. vol. xii. p. 38 *et seq.*

Mountain-limestone was at once met with, to the entire exclusion of the Coal-measures.

In Brittany and the West of France, the Lower Carboniferous deposit rests at once upon the Lower Devonian, as is seen between Sablé and Juigné and at the coal-pits of Fercé. The anthracitic group of the Department of the Sarthe (Nos. 14, 15, 16 of the preceding section, p. 408) is composed of conglomerates, sandstones, shale, coal, and limestone, all unquestionably belonging to the Carboniferous series, of which they constitute a lower member. In the West of France, as at St. Pierre-la-cour, between Laval and Rennes, they are unconformable to the superjacent Coal-measures.

A like physical arrangement has already been alluded to as occurring throughout Germany. True Carboniferous Limestone, with large Producti, was described by Professor Sedgwick and myself at Hof, in Bavaria *, as being there inclined conformably with the Devonian on which it rests, and unconformably to the horizontal Coal-measures of Bohemia. Similar physical relations led Élie de Beaumont to group the Lower Carboniferous division with the Lower Palæozoic rocks to which it is conformable, though their respective organic remains are so very distinct. The geologist who combines stratigraphical with zoological evidences is therefore bound to state that the dislocations of the older rocks on the Continent have occurred at periods different from those of formations of the same age in Britain and America. In both the latter countries the great superjacent Coal-measures have partaken of the movements which affected the limestones whereon they rest. Thus we are still further confirmed in the belief that all fractures of the crust of the earth are local phenomena only.

As the strata containing large Producti (Sablé, Fercé, Juigné, La Bazouge, &c.) were shown to be truly of Carboniferous age, their fossils being absolutely those of the Mountain-limestone of England, it followed that many other considerably metamorphosed rocks in the South-east of France, but in which such fossils were detected, must also be referred to the same era of formation. Thus de Verneuil and Jourdan have proved that the schists, slates, and quartz-rocks of Central and Eastern France, particularly in the Department of the Haute Loire (Roanne to Lyon), which from their crystalline aspect had been grouped with those of a much older epoch, are clearly to be classed with the Carboniferous rocks. Though in parts highly altered, and having a very antique and crystalline aspect, they have been found to contain the well-known fossils of the Coal-period, Productus Cora, Chonetes papilionacea, Spirifer bisulcatus, Orthis crenistria, Goniatites diadema, &c.

It was in the northern extension of this chain of hills from Thiers to Cusset near Vichy, where the schists have a still more ancient character and are pierced by numerous porphyries and syenitic rocks, that, by the help of a few fossils, I was enabled to satisfy myself that the slaty rocks on the banks of the Sichon also belonged to the Carboniferous era †.

The Permian rocks of France may be disposed of in a few words; for they are very inadequate representatives of the diversified and complex assemblage of strata which constitute the Permian of Russia, Germany, and Britain. The lower portion of a series of red rocks in the Vosges Mountains, usually known as the 'Grès des Vosges,' is considered by Élie de Beaumont and myself to be of this age; and it has also been shown how other red sandstones, near Lodêve in the South of France, may, on account of their Plants, be classed as Permian.

* Trans. Geol. Soc. Lond., 2nd series, vol. vi. p. 298, pl. 23. f. 15.
† Quart. Journ. Geol. Soc. Lond. vol. vii. p. 13.

Professor Coquand, moreover, has described a succession of strata in the same tract, which he views as being also of Permian age *, thus confirming the opinions of M. Adolphe Brongniart and the authors of 'Russia and the Ural Mountains' †. Nowhere, however, within the limits of the country is there any limestone to represent the great calcareous centre or Zechstein; and the group is therefore wanting in those animal remains which constitute its essential distinctions.

In the hard and subcrystalline rocks of the South of France, which lie to the south of the great granitic plateau of that region (that is, the Montagne Noire, between Lodêve and Pezenas), no clear succession of the older rocks has been determined; and until recently they were considered, to a great extent, unfossiliferous.

Within these few years, however, MM. Fournet and Graff discovered at Neffiez near Pezenas ‡ a very singular small *oasis*, in which there occur thick masses of green slate with large Lower-Silurian Asaphi, succeeded by other beds laden with several characteristic Lower-Silurian fossils, whilst higher strata contain Cardiola interrupta and Graptolites. Then there are red limestones charged with unequivocal Upper-Devonian types, as recognized by de Verneuil; these are Goniatites amblylobus and Cardium palmatum of Westphalia, Nassau, and the Eifel. This rock is also identical with the 'Marbre griotte' of the Pyrenees, which Leopold von Buch classed as Devonian. Again, we have in this one little spot true Carboniferous deposits; for, though there are only a few beds of their lower members, the fossils are unequivocal—namely, Productus gigas, P. semireticulatus, Euomphalus acutus, Caninia gigantea, &c. The series is even terminated upwards by some workable beds of coal.

Such, says de Verneuil, is the palæontological order of the strata, if we look only to the fossils, and compare them with those of all other known countries in the world.

Whilst this is the universal and normal order in America, Asia, and Europe, these members of the series, so distinct elsewhere, were at one time supposed to be physically intermixed at this little anomalous spot of Neffiez! but MM. Fournet and Graff, who had called attention to this apparent intermixture of Silurian, Devonian, and Carboniferous fossils, no longer maintain the opinion they at first expressed. In fact, the tract has manifestly been subjected to violent dislocations; and my associate de Verneuil has always thought that the apparent anomaly is due to one of those inversions or reversals known in the Alps, America, and many other regions, and to which I have already called attention in my remarks on Britain and Germany (pp. 97, 145, 403).

The Palæozoic formations again protrude to the surface in the Corbières to the south of the plains of Languedoc; and, rising from beneath the younger deposits, they also form, as has long been known, a central portion of the Pyrenees. In that chain, the altered limestones, or 'Marbres griottes' §, which occur as concretionary masses in the schists, and are charged with Goniatites, are unquestionably Devonian. The schists of Gèdre, between St. Sauveur and Gavarnie, and also at Les Eaux Bonnes and other places noticed by M. Leymerie ‖, contain fossils of the same age.

Just as in the Eastern Alps, the Ural, and many mountain-chains which have

* Bull. Soc. Géol. France, 2nd series, vol. xii. p. 128; and xiv. p. 13.

† See 'Russia and the Ural Mountains,' vol. i.

‡ Bull. Soc. Géol. France, 2nd series, vol. viii. p. 44.

§ This 'Marbre griotte' of the valley of Campan is well described by M. Dufrénoy.

‖ See Bull. Soc. Géol. France, 1856, where the list of fossils given by M. de Verneuil would lead us to suppose that the rocks near Les Eaux Bonnes belong to the Lower Devonian. True Lower Devonian fossils have been detected recently (1865), by M. de Mercey, between Les Eaux Bonnes and Cauterets, among which de Verneuil recognized some species identical with those of Leon and Asturias.

undergone much metamorphism, the observer fails to detect here the equivalents of the Lower Silurian Rocks *; but in a few spots the Pyrenees afford traces of one member of the system, as characterized by Graptolites, Cardiola interrupta, and Orthoceras Bohemicum and O. gregarium—fossils which have already been spoken of as probably representing the base of the Upper Silurian division. In the absence then of Lower Silurian rocks, the Pyrenees present a strong contrast to the 'Montagne Noire,' near Neffiez, where some of the largest Trilobites of that age have been found.

Palæozoic Rocks in Spain, Portugal, and Sardinia.—To the south of the great chain of the Pyrenees, where several of their formations occur in a more or less crystalline state, the Lower Palæozoic or Silurian rocks have much the same development as in France. Our acquaintance with the order of these rocks in Spain is chiefly due to the researches, during the last fifteen years, of my colleague de Verneuil and his friend Ed. Collomb; for, whilst it is true that Spanish and French geologists and mineralogists of ability, such as Ezquerra del Bayo, Casiano de Prado, Schultz, Paillette, Amalio Maestre, and others, had made themselves well acquainted with the physical and lithological features of many tracts in which the older rocks prevail, and that the eminent French mining engineer, Le Play, had published a sketch of the mineral structure of the Sierra Morena, it was only by a personal examination of the imbedded fossils of the strata in each chain that the relative age of the rocks was at length fixed and correct comparisons established †.

A glance at any good map shows that the Peninsula is marked by dominant chains of mountains more or less parallel, trending from west-south-west to east-north-east, and separated from each other chiefly by enormous basins of Tertiary age, which, though at much lower levels, are still at considerable heights above the sea, and constitute, on the whole, what Humboldt has termed a great plateau ‡.

Let us first say a few words on the chief central ridge of the kingdom, the Guadarama, which passes to the north of Madrid. The late Casiano de Prado,

* Bull. Soc. Géol. Fr. sér. 2. vol. i. p. 137.

† This observation has reference solely to the order and classification of the stratified rocks; for, in reference to mineralogy and other departments of geological science, a vast number of works and memoirs have been written during the last century, by native and foreign authors. See de Verneuil and Collomb, Coup d'œil sur la Constitution Géologique de quelques Provinces de l'Espagne, Appendice Bibliographique, Bull. Soc. Géol. Fr. 2nd ser. vol. x. p. 138, where a very copious list of authors is given, comprising upwards of 160 publications in the last hundred years. At the Meeting of the British Association for the Advancement of Science in 1850, I presented, on the part of M. de Verneuil, his remarkable work, the first geological map of the whole Peninsula, accompanied by a short notice. Since that time my colleague has often revisited Spain, and in 1864 published with M. Collomb a geological map of the Peninsula. The high antiquity of the crystalline rocks of Gallicia is affirmed on the authority of M. Schultz, who has made a geological map of that province, and is completing a beautiful map of the Asturias. The tracing of Silurian rocks into the Toledo Mountains is due to the zealous researches of the late Casiano de Prado, to whom we also owe the proofs that the quicksilver-mines of Almaden are in Lower Silurian rocks. Many of the fossils (chiefly Devonian) from the North of Spain were first found by M. Paillette, whose description of the rocks of that age is given in the Bull. Soc. Géol. France, vol. ii. p. 439. A sketch of a geological map of Spain was also published by M. Ezquerra del Bayo in Leonhard und Bronn's N. Jahrbuch, 1851. In several of his excursions M. de Verneuil was accompanied by M. Collomb, who has likewise given a sketch of the general views they then acquired of the structure of the Peninsula in the Bibliothèque Universelle de Genève. Even whilst I write M. de Verneuil is again in Spain preparing a new edition of his Map (April 5, 1867).

‡ The mean altitude of the Plateau of Old Castile, for example, is from 2150 to 2200 English feet, and that of New Castile about 300 feet less.

the zealous Spanish geologist *, who published two years ago an excellent geological map of the Province of Madrid, has shown that the gneiss and other crystalline schists and subordinate limestones pierced by granites, and much altered, rise to heights exceeding 7000 feet. These are flanked by schists and siliceous sandstones, which are classed as Lower Silurian, because they contain the Cruziana or Bilobites, a fossil which occurs in rocks of that age in France and Britain.

A suggestion made by Barrande, from an inspection of three imperfect heads of the Trilobite Ellipsocephalus, collected by Casiano de Prado in the Montes de Toledo, that the 'Primordial Zone' is also present in the Peninsula, has been completely justified by Casiano de Prado himself, who discovered Paradoxides and Conocephalus in a band of red limestone in the Province of Leon (see Bull. Soc. Géol. Fr. 1860, vol. xvii. p. 516, the fossils being described by de Verneuil and Barrande). More recently, in 1863, MM. de Verneuil and Louis Lartet also discovered a 'Primordial' Silurian range with the same species of Trilobites near Daroca; they found it also in various parts of the Silurian Sierra which extends from Daroca to Moncayo ('Revista Minera,' vol. xiii. p. 479).

The upper part of the Lower Silurian corresponding to the Caradoc, if not in part to the Llandeilo formation, is fully developed in Spain, especially, as M. de Verneuil indicates, in the Sierra Morena, the Montes of Toledo, and the Sierras of Aragon, near Origuela, Molina de Aragon, &c.

In crossing the Sierra Morena from Almaden on the north to Cordova on the south, de Verneuil recognized an ascending order. The inferior strata consist of schists and some intercalated dark limestones, with quartzose sandstones—the latter not unlike the British Stiper Stones (see p. 39). These, being the hardest and least decomposable portions of the strata, form the summits or peaks of the low ridges, and clearly exhibit the strike or range of the masses, which is from east 10° north, and west 10° south. The celebrated quicksilver-mines of Almaden occur at the foot of one of the quartzose ridges of this age, as determined by Casiano de Prado †, who published in the 'Bulletin' of the Geological Society of France (vol. xii. p. 182) a geological map of this tract. The same zealous explorer also traced the continuity of Lower Silurian rocks from the Sierra Morena into Gallicia,—the range passing through Estremadura and by the Sierras of Gata and Francia. Most of the mountains which, extending from S. to N., form the boundary between Spain and Portugal may thus be considered to be of the same age. The Lower Silurian rocks of the Sierra Morena range eastwards to the city of Alcarraz, where they subside under the Secondary formations of Murcia.

The long chain of the Sierra Morena, which extends from Alcarraz to Cape St. Vincent, is separated from the metamorphic and crystalline coast-range of the Mediterranean by a mountainous country composed of Secondary and Tertiary rocks. The ages of all the rocks in this coast-range, of which the Sierra Nevada is so prominent a feature, are still doubtful. One of the mineral characteristics of that lofty region is, that it contains immense masses of limestone which occasionally are dolomitic, and rise into lofty peaks, unlike any portion of the outline in the Silurian and Devonian rocks of the Sierra Morena. It has indeed been suggested by M. Pellico, that the southern coast-chain may be of

* In the summer of 1866 this high-minded, able, and undaunted explorer died at Madrid, the day after his return from the Canary Islands, a victim to his unbounded zeal for the advancement of geological science. His death is a serious loss to the progress of Spanish geology.

† The mercury of Almaden is said not to form veins, but to have impregnated the vertical strata of quartzose sandstone associated with carbonaceous slates. The occurrence of mercury with such rocks is still more remarkable in the Asturias, where mines of mercury are worked in coal-strata.

Silurian age, on account of the existence of very imperfect Orthoceratites and Corals *. Judging, however, from the mineral structure of the deposits and the nature of the intruding greenstones, viz. the abundance of limestone, and the absence of granite, so common in the Silurian range of the Sierra Morena, M. de Verneuil is disposed to think that these metamorphosed rocks, or at least the upper calciferous part of the mass, may be of Triassic age. It is well known that these rocks are the sites of some of the richest mines of argentiferous galena, particularly near Carthagena, in the Sierra Almagrera, as well as in the Sierra di Gador and at the foot of the Sierra Nevada.

The fossils found in the Sierra Morena and the Toledo Mountains occur usually in black shivery schist. The most prevalent is perhaps the Calymene Tristani; but recently many other of the well-known French forms of Trilobites, in all about twenty species, have been detected†, including Illænus Lusitanicus? or Il. Salteri, Asaphus nobilis, Calymene Tristani, C. Arago, Phacops socialis, Ph. Dujardini, Dalmania socialis, and D. Phillipsi, Barr.; Trinucleus Goldfussi, Barr.; Homalonotus (Plesiocoma) rarus, Placoparia Tournemini, Orthoceras duplex, Bellerophon bilobatus, Redonia Deshayesiania, &c.; also occasionally Graptolites have been discovered, of species well known in Brittany, Normandy, Bohemia, and Saxony.

Now, whilst most of these fossils are also found, as has been stated, in the slaty schists of Angers and Vitré, in France, which the French geologists have mapped as Lower Silurian, several are identical with Bohemian species published as of the same age by Barrande. It is also well worthy of notice, since the fossils generally resemble so much those of Central Europe, that the very common British species Bellerophon bilobatus, and the remarkable Cephalopod Orthoceras duplex (so characteristic of the Lower-Silurian fauna of Scandinavia and the North of Europe), should also be found, though very rarely, as M. de Verneuil remarks, in this southern parallel. Some of the Silurian fossils enumerated were first discovered by M. Casiano de Prado, near Molina, in Aragon. They have subsequently been traced there by the same geologist, and also along the eastern borders of New Castile, where they occur in black Graptolite-schists which jut out from beneath the Secondary deposits. These Silurian schists have further been followed by the same author in the mountains of Checa, Horea, Origuela, and Monterde.

If any Upper Silurian rocks can be said to exist in Spain, they are, as in France, only thin courses of black schist, with spheroidal calcareous concretions in which Graptolites occur, together with Orthoceras Bohemicum and O. styloideum of Barrande, and the British Cardiola interrupta. Such rocks, faintly exhibited in parts of the Sierra Morena, are also seen on the south flank of the Pyrenees, near Ogasa and San Juan de las Abadesas, where they are recognized by the presence of Cardiola interrupta and Orthocerata ‡. It is also supposed that a band of siliceous limestone pierced by elvans, or granitic dykes, and which extends along the south side of the chain from Gerona, by Hostalrich, to Barcelona, may be referred to the same age, Orthocerata having been found in it near the

* The fossils, alluded to by various authors, were to be seen only in very old slabs used as floor-stones in some of the houses of Carthagena. M. de Verneuil went to that town to examine these slabs, and recognized in them two of the commonest fossils in Sweden, namely Orthoceras duplex and Asaphus expansus. The red colour of the rock, as well as the fossils, suggested to him the idea that these slabs must have been brought from Scandinavia. If this be the case, in the metamorphic rocks of the south coast-range no organic remains are at present known.

† In an examination by Casiano de Prado, Eusebio Sanchez, and E. de Verneuil. For details see the memoir of Casiano de Prado, de Verneuil, and Barrande (Bull. Soc. Géol. Fr. ser. 2. vol. xii. p. 964).

‡ By MM. de Verneuil and de Lorière. The fossils near San Juan de las Abadesas were discovered by M. Amalio Maestre; they have been quoted by Prof. Leymerie, from near St. Béat on the north side of the Pyrenees, and they exist also in Sardinia.

last-mentioned city by the late Mr. S. P. Pratt, who explored several tracts in Spain *.

Devonian Rocks in Spain.—Devonian rocks are developed in the Sierra Morena north and south of Almaden, and occur in several repetitions troughed by Lower Silurian rocks, the fossils lying generally in sandstones or in small bands of impure limestone. The most characteristic species are Productus subaculeatus, Leptæna Dutertrii, Spirifer Verneuilii, Sp. Archiaci, Sp. Bouchardi, Orthis striatula, Atrypa reticularis, A. Orbignyana, A. concentrica, Phacops latifrons, &c. All these but one (A. Orbignyana) are common fossils at Boulogne; and there are many others which are well known in French and German localities, besides some species peculiar to Spain. In the southern parts of Cuenca, near Hinarejos, de Verneuil and Collomb also detected deposits containing Lower-Devonian fossils, including the Spirifer macropterus of the Rhine †; and in 1852 the equivalent deposits were traced at the eastern extremity of the Guadarama range between Atienza and Siguenza, by de Verneuil and de Lorière.

Whilst the western parts of the Sierra Cantabrica, extending from the high-road from Leon to Oviedo, are now known to be composed of quartzose and schistose strata of Silurian age, Casiano de Prado having detected Graptolites in them, the middle part of this chain presents a very rich development of Lower-Devonian deposits ‡. These rocks consist of red sandstone, shale, and grey limestones, which, owing to powerful dislocations, assume bold and peaked forms, visible at great distances from the plains of Castile. They are as prolific in mineral wealth as in organic remains, the iron of Mieres and Sabero being extracted from them §. Thanks to the labours of Schultz, Casiano de Prado, Paillette, de Verneuil, and d'Archiac, the successive formations of these countries are now becoming much better known.

Carboniferous Rocks of Spain.—Proceeding to the east, the Devonian rocks of the Sierra Cantabrica are succeeded in the Asturias by the richest Coal-field in Spain. Its lower beds consist of massive limestones, having so much resemblance to the Devonian rocks on which they lie, that, except for their respective organic remains, they could with difficulty be separated. The fossils, however, are decisive of the superior rock; for among them are several well-known British species of Productus, such as P. semireticulatus, together with Spirifer Mosquensis, and even Fusulina cylindrica, the characteristic Foraminifer of the Carboniferous Limestone of Russia. Above these masses, beds of coal first begin to alternate with other and smaller courses of limestone; and therefore in Spain as in Russia, and in the Lower Coal-beds of Scotland, the carbonaceous portion is subordinate to the Carboniferous or Mountain Limestone. Then follow conglomerates and sandstone, with fossil Plants, said to have a thickness of 10,000 feet, and which, probably representing the Millstone-grit of Britain, are copiously charged with coal, about eighty beds of it having been recognized, in strata for the most part vertical.

* See Quart. Journ. Geol. Lond. vol. viii. p. 270.

† M. Jacquot quotes also the Leptæna Murchisoni in his 'Esquisse Géologique de la Serrania de Cuenca' (1866).

‡ M. de Verneuil has identified nearly 80 Devonian species from Sabero in Leon and from Ferrones and Aviles in the Asturias, which ought, he says, to be places of pilgrimage for all collectors. Of the works on this region, see, 1st, 'Resena geognostica del principado de las Asturias, Vista geolog. sobre Cantabria,' by G. Schultz, Insp. Gen. de Minas. 2nd, 'Recherches sur quelqu'unes des roches des Asturies, et les fossiles qu'elles contiennent,' par Paillette, de Verneuil, et d'Archiac, Bull. Soc. Géol. Fr., 2nd series, vol. ii. p. 439. 3rd. 'Sur les Environs de Sabero (Leon),' par Casiano de Prado et de Verneuil, Bull. Soc. Géol. Fr. 2nd ser. vol. vii. p. 137.

§ Though the coal of Sabero is apparently included among the Devonian rocks, M. Casiano de Prado thinks that this appearance may be due to inversion and folding of the various strata; so much has this Palæozoic tract been convulsed.

The limestones that form the inferior limit of these Carboniferous deposits truly vindicate the propriety of the old English name Mountain-limestone; for they rise to the highest points of the Cantabrian chain, and constitute the mountains of Cabrales and Cobadonga, as well as the Peaks of Europe (Picos de Europa). They also advance to the sea near Ribadesella, and penetrate on the east into the Provinces of Santander and Palencia*. The last-mentioned of these Provinces has during the last three years undergone a special and laborious survey by the late M. Casiano de Prado, who published a map, founded on his trigonometrical observations, which must prove of signal advantage to this rich mining region. The same untiring and successful explorer demonstrated that in no other part of Spain is the Carboniferous Limestone so rich in fossils, inasmuch as he detected at least 100 species in this one tract.

The Carboniferous deposits of the Sierra Morena range along the southern part of that chain. Like similar formations in the north of Spain, their lower beds generally contain limestones in which occur the same species of Productus and some marine fossils that are known in other regions. The coal is chiefly associated with overlying conglomerates and sandstones; some of it, however, as in the Asturias, is said to lie in the calcareous series. The best coal-fields of this southern region are at Villa Nueva del Rio near Seville, and in the neighbourhood of Belmez, between Almaden and Cordova, where the strata are highly inclined.

On the flanks of the crystalline schists, probably metamorphic, which form the Sierras east of Burgos, towards Brieva de Guarros and Escaray, are also masses of sandstone and shale with impressions of Plants and traces of coal, associated, as in the other Spanish coal-fields, with a few marine fossils. These rocks are mentioned only to show how generally the same Palæozoic succession prevailed over the Peninsula before the country was thrown up into those ridges which now form the lines of separation between its different provinces.

Whatever be their direction or inclination, the Silurian, Devonian, and Lower Carboniferous rocks of Spain have all been conformably and, apparently, simultaneously elevated, as in France.

The existence of Permian rocks in Spain is rather doubtful, no fossils of that age having yet been found in so southern a part of Europe. Led, however, by mineral analogies and other characters, an able French engineer, M. Jacquot, has recently proposed to range as Permian a great arenaceous red deposit in the Serrania de Cuenca, which he considers to be the equivalent of the 'Rothliegende' and the 'Grès des Vosges' (Esquisse géologique de la Serrania de Cuenca, 1866).

Although the present work does not treat of the Secondary rocks, it is due to my eminent associate de Verneuil, and his fellow-traveller, M. Collomb, to state that, besides tracing Jurassic and Cretaceous deposits, they detected true Muschelkalk fossils near Mora on the Ebro, and in various other localities, clearly demonstrating the existence of Trias in the Peninsula†.

Silurian and Carboniferous Deposits in Portugal.—English geologists are in-

* During the summer of 1852, MM. de Verneuil, Casiano de Prado, and Lorière ascended one of these lofty peaks of Mountain-limestone, and found, by barometrical observation, that it was 2500 metres, or about 8200 English feet, above the sea. It was covered with snow on the 1st August. In the summer of 1856, M. Casiano de Prado ascended the highest of all these peaks, and determined its height to be 2650 metres, or 8692 English feet!

† Some badly preserved fossils of Triassic age had been previously observed by Casiano de Prado, de Verneuil, and de Lorière, at Royuela, [illegible] of Albaracin. Besides giving to the public a valuable table of the chief altitudes of this rugged and rocky region (see Comptes Rendus de l'Acad. des Sciences, vol. xliv. p. 1299), MM. de Verneuil and Collomb have published a map of the district (1864). It has been reported that lately Professor Vilanosa has discovered new localities where Triassic fossils are found.

debted to the late Mr. Daniel Sharpe for nearly all they know of the real structure and succession of the sedimentary rocks of the kingdom of Portugal, whether of Palæozoic or Secondary age*.

Of the former, two notable examples have been pointed out, and probably many more will be detected, in addition to another case to be presently noticed. The first noticed was at Vallongo, in the immediate environs of Oporto. There the Lower Silurian rocks, precisely of the same mineral type as those of France and Spain, and including the same fossils, together with two or three British forms and some new species, rise up in highly inclined and vertical strata; and, as at Angers and other places, are quarried for roofing-slates.

An anomalous arrangement of the lower and higher deposits, however, is there apparent. The coal-field of Vallongo, which has supplied a considerable portion of the city of Oporto with fuel, and in which are certain Plants not distinguishable from those of the Carboniferous era, dips under the Lower Silurian schists with their characteristic Trilobites! Now, if this had been really the normal position of the plant-bearing strata, we should have had to believe in the existence of an ante-Silurian flora composed of the same terrestrial vegetation as that which, in other regions, we find only when we approach to the horizon of the great coal-fields. Believing fully in the accuracy of Mr. Sharpe's sections, I saw, however, from his own faithful description of this district and the region to the south of it, that we might without difficulty surmise how this apparent anomaly has been brought about. The Lower Silurian rocks and the contiguous Coal-strata (for the coal is not found within the body of the lower slates) are both situated between two ranges of eruptive rocks,—the one on which Oporto stands being granite, and the other, to the east, syenite. On the flanks of the granite of Oporto, micaceous schists abound, which, if metamorphic, may be of any age; but, even if these be of ante-Silurian date, we have simply to imagine a trough of coal, of the true Carboniferous date, placed between these schists, on the one hand, and the clay-slates with Lower Silurian fossils, on the other, and then, by a movement of which we have many well-authenticated examples both in Europe and America, that this trough has been placed locally in an inverted and dislocated position.

The enormous length of time which must have elapsed between the accumulation of the Lower Silurian and the formation of the Devonian rocks, and during which interval we have here no evidence of Land Plants having appeared, forbade us, indeed, to adopt the view of an infra-Silurian coal, until we had exhausted every other means of explaining the anomaly; for the plications of the strata in Belgium, as delineated by M. Dumont, or those in Westphalia, mentioned in this volume (p. 403), or those in the Alleghanies (described by Prof. Rogers), explain how strata really inverted in one place, may be followed until they resume their regular order.

Wedged in, as these Silurian and Carboniferous masses of Portugal are, between two flanking parallel ridges of eruptive rock, it was no doubt difficult to detect their regular order—though, even in describing a transverse section from Oporto to Aveiro, Mr. Sharpe himself stated that clay-slates, lying on gneissose and micaceous schists, are surmounted by carbonaceous shale and red sandstone. This I conceived to be the natural order, because even in the adjacent districts of the north of Spain, to which that geologist first pointed attention as being likely to contain Silurian rocks, there are no traces whatever of anthracitic coal-measures beneath or associated with such ancient rocks, all the Carboniferous deposits of that region being, as previously stated, in their usual and normal position.

* See Quart. Journ. Geol. Soc. Lond. vol. v. p. 142; vol. vi. pp. 101 & 135; vol. ix. p. 146.

The question, indeed, was thus settled whilst the first edition of this work was printing; for Mr. Sharpe then communicated to the Geological Society of London * the discovery of fossils, accompanied by important observations made by M. Carlos Ribeiro, which showed the prolongation of the same axis of Silurian rocks from north-north-west to south-south-east, far beyond the Douro. The rocks in question form, in fact, the crest of the Serra de Busaco, on which Wellington and Massena first tried their strength, and thence extend to the south-south-east beyond the River Mondego † into the Serra de Mucella. During the greater part of their course, the Silurian rocks are surrounded or flanked by older unfossiliferous masses, consisting of mica- and chlorite-schists with clay-slate &c. These crystalline rocks are at once followed by dark-brown indurated shales, somewhat slaty, which abound with Lower-Silurian fossils, among which Mr. Sharpe recognized numerous species of Leptæna and Orthis, with Trilobites, many of them previously undescribed. He identified indeed the most characteristic of the Trilobites with species well known elsewhere—Trinucleus Pongerardi, Calymene Tristani, and C. Arago of Brittany, also Phacops socialis of Bohemia. The lower fossiliferous rock of Busaco therefore obviously represented the oldest zone in France and Spain then known to contain remains, and was identical with that described by Mr. Sharpe at Vallongo near Oporto. That zone is surmounted, and chiefly along the middle of the ridge of Busaco, by a band of hard ochreous shale, frequently altered by eruptive masses of greenstone and generally breaking up into prisms, the bedding being scarcely distinguishable. This rock, probably equivalent to the sandstone of May in Normandy, is full of small Corals, such as Favosites fibrosus, besides species of Retepora (?), also many simple-plaited Orthides, and some Trilobites common to the subjacent deposit,—the whole of the evidence proving clearly that it is simply a superior member of the Lower Silurian group. In short, the uppermost of these Silurian rocks in Portugal is apparently the same zone we have been considering in Spain and France—viz. a bluish shale or argillaceous schist, containing the well-known British fossils Graptolites Ludensis and Cardiola interrupta, with other Mollusks, also numerous crushed specimens of Orthoceratites.

Now all these Silurian rocks are overlain unconformably by a deposit of true Carboniferous age, the shales and sandstones being full of Ferns and other Plants of species common in the Coal-deposits of France and Germany. Thus, when traced out, the apparent anomaly at Vallongo was resolved by a case perfectly analogous to the examples given in previous parts of this work, and the order of succession was proved to be the same as in other regions.

The exact age of many of the crystalline stratified rocks which form the hilly and mountainous region separating Portugal from Spain, and wrapping round the north of the former country, has not yet been accurately defined. That many of them are the metamorphosed varieties of the Silurian and other Palæozoic rocks under consideration is almost certain. In parts of Portugal they are richly metalliferous; and some of their products have been well described by J. A. C. das Neves Cabral, who acted as the Commissioner of the Portuguese Government at the International Exhibition in London in 1862.

Sardinia and Upper Italy.—Extending our inquiry eastwards from Northern Portugal and Central Spain to like parallels of latitude on the other side of the

* Quart. Journ. Geol. Soc. Lond. vol. ix. p. 135.

† The author craves pardon of the reader for stating that, when a young Ensign (sixteen years of age) in the 36th Regiment, he disembarked, on the 1st of August, 1808, at the mouth of this River Mondego, and close to the boat from which Sir A. Wellesley first stepped on the shore of the Iberian Peninsula. After the victories in Portugal he was in that Division of the Army, under Sir John Moore, which marched through so large a portion of Spain from Badajos to the Escorial, and thence northwards, terminating in the retreat to Corunna.

neighbouring portion of the Mediterranean, we again meet in Sardinia with a similar succession of Palæozoic deposits. Geologists owe this determination to the researches of General de la Marmora, so long favourably known to geographers for his beautiful topographical map of that island. Judging from certain Orthidæ and Orthocerata which this author sent to me in the year 1848, I had no doubt that Silurian rocks existed in Sardinia, as laid down indeed by Collegno in his geological map of Italy. I have since been informed by M. Barrande, who has personally inspected the rocks and fossils in the southern part of the island, near Flumini Maggiore, that in his opinion both Lower and Upper Silurian rocks are there present.

In addition to the work by General de la Marmora, accompanied by an elaborate map, it has been shown by Professor Meneghini of Pisa that several of the fossils collected by the General and his assistant M. Vecchi are well-known Silurian forms. Among these may be mentioned Orthis Lusitanica, Sharpe, O. testudinaria and O. vespertilio, Sow., &c. Other fossils are, on the contrary, Upper-Silurian types, such as Orthoceras ibex, O. gregarium ?, Sow., and several others, besides Cardiola and Avicula.

General de la Marmora informs us that all these Silurian or other rocks *, and the metamorphic masses with which they are associated, are distinctly surmounted by strata containing anthracitic coal, charged with many of the fossil Plants which prevail in the old Coal-deposits of other regions. Thus among the fossils from Seni and Sculo Professor Meneghini has recognized Pecopteris arborescens, P. dentata, P. unita, P. polymorpha, P. hemiteloides, and several others, with species of the genera Odontopteris, Neuropteris, Sphenophyllum, Annularia, Asterophyllia, Sigillaria, Syringodendron, and an abundance of the well-known Calamites Suckowi.

In fact, the strata in which these Coal-plants occur, and which terminate downwards in conglomerates †, rest in completely discordant positions on the older rocks, and in this highly altered tract are covered by dolomites of the Jurassic age.

Schists and conglomerates, though not so carbonaceous, but charged with many Plants similar to those of Sardinia, have indeed been described by Professors Meneghini and Savi in the older rocks of Tuscany, which at Jano contain Productus semireticulatus and other Carboniferous fossils. This group of rocks is therefore no longer to be vaguely classed as Palæozoic, but takes a definite place, like parts of the Carinthian Alps near Bleiberg, where the same animal-remains occur, and thus is proved to be truly of the Carboniferous epoch. These facts, which were unknown in 1848, when I last published upon the Alps and Apennines ‡, are most important, and lead us to infer that the traces of the coal which are associated with certain Land Plants in parts of the Western Alps, are also of the old Carboniferous age; for the conglomerates and schists with which such plants are associated in the Alps are the precise equivalents of the 'Verrucano' and schists of Sardinia and Northern Italy; and these lie beneath strata of Triassic, Liassic, and Jurassic age.

It has already been stated that rocks containing Silurian, Devonian, and Car-

* It is right to state that whilst M. de Verneuil has seen unquestionable Upper-Silurian fossils from Sardinia, which on the part of General de la Marmora I submitted to him, he is of opinion that some of the fossils (of which, however, he only saw drawings) are of Devonian age. It is probable, therefore, that the succession will eventually be found to be similar to that of Spain.

† See my Memoir on the Alps, Apennines, and Carpathians, Quart. Journ. Geol. Soc. Lond. vol. v. p. 157, and particularly its translation into Italian by Professors P. Savi and Meneghini, entitled 'Struttura Geologica delle Alpi, degli Apennini e dei Carpazi,' followed by their 'Considerazioni sulla Geologia della Toscana' (Florence, 1850), in which these distinguished Italian geologists announced the important discovery of the true old Carboniferous formation in the hills near Volterra.

‡ Quart. Journ. Geol. Soc. Lond. vol. v. pp. 167, &c.

boniferous shells occur in the Austrian or Eastern Alps. With these data before us, and looking to the prodigious amount of metamorphism, dislocation, convolution, and inversion to which the component parts of that chain have been subjected in their extension to the west, we can have little difficulty in imagining how the Silurian and Devonian strata have there passed into a crystalline state; while the sole remnants of the Carboniferous rocks, identifiable through their organic remains, are the plant-bearing conglomerates and schists of the Valorsine and of certain tracts around Mont Blanc, which have been so twisted up as often to appear to be intercalated among the Secondary rocks. Indeed the long-disputed question of the age of the anthracites of the Tarentaise has been at last settled by the labours of MM. Vallet, Lory, Pilhet, and A. Favre; and, since the Meeting of the French Geologists held in 1861 at St. Jean de Maurienne, it has been admitted by most geologists that these schists belong to the true Carboniferous era.

Note.—The ensiform bodies occurring in the Trilobite-slates of St. Leonhard, La Sarthe, France, and supposed by M. Marie Rouault to be Ichthyolites, have not the least relation to Vertebrata, or possibly to anything of higher order than Fucoids. See Appendix G of the last edition of this work, and Comptes Rendus de l'Acad. vol. xlvii. p. 469. In fact, no trace of Vertebrata has been discovered in the Silurian rocks of France.—*April* 1867.

CHAPTER XVIII.

SUCCESSION OF PRIMEVAL ROCKS IN AMERICA.

ORDER OF THE PALÆOZOIC ROCKS IN SOUTH AMERICA (THE ANDES), THE UNITED STATES, AND BRITISH NORTH AMERICA.

THE researches of geologists have demonstrated that there was a wide diffusion of similar groups of animals over the globe during the Primeval Periods. A striking proof of this fact is, that many of the Palæozoic fossils which we have followed over the various countries of Europe are found to have unquestionable equivalents in the continent of America.

It is in America that the discovery of animal life in the Laurentian or oldest known sedimentary rocks was made, which has been followed by a similar discovery in Europe. The highly important researches of Logan and his associates, demonstrating that all the Palæozoic rocks, so well described in the United States by Hall and others, repose upon the double series of highly metamorphosed gneissic strata in which the Eozoon Canadense occurs, have been explained in the First Chapter of this work (p. 11 *et seq.*). These Laurentian rocks, though very extensive in North America, constitute a low mountain-chain compared with the much younger and loftier Andes, which, as described by Humboldt, form the main geographical axis of the great western continent.

The oldest of the slaty and quartzose formations so admirably delineated by that great traveller, in whose youthful days fossils were little studied, have since been referred, by means of their organic remains, to the Silurian System. Following up the inquiries of his precursor, Alcide d'Orbigny showed, in maps and sections, as well as by descriptions*, that these rocks contain the fossil Sea-weed (?) Cruziana (or Bilobites), with Graptolites, Lingulæ, Orthidæ, and Trilobites of the genera Asaphus and Phacops (Calymene). He further pointed out that these Silurian masses are succeeded by sandstones and siliceous strata probably of Devonian age, and the latter by limestones and other rocks, charged with fossils of the Carboniferous era. Subsequently Mr. D. Forbes, correcting some errors of d'Orbigny, has thrown much new light upon the succession and contents of these Palæozoic rocks in Chili and Peru †.

The Silurian slates and schists form enormous bands; and examples of them are well exhibited on the declivities of the plateau of Bolivia, as well as on the flanks of the Cordillera extending from Sorata to Illimanni. They are, in most

* See 'Voyage dans l'Amérique Méridionale,' tome iii., Partie Géologique, Paris, 1842. In justice to my friend Mr. Pentland, so well known to geographers by his measurements of the high peaks of the Peruvian Andes, around the lofty Lake of Titicaca, let me say that he was the first person who made me acquainted with the occurrence of Silurian Trilobites in the slaty rocks of this chain.

† See Quart. Journ. Geol. Soc. vol. xvii. p. 7 &c.

parts of their range, metamorphosed, and in this state extend from Chili on the south * through the Rocky Mountains to the north. Even in Texas they have been recognized by F. Römer †. Including the quartz-rocks which are associated with them, they constitute the chief matrix of the gold and other metals so extensively worked along this great chain (see Chapter XIX.). It has been suggested by d'Orbigny ‡ that the huge stratified quartz-bands described by Humboldt may be the altered equivalents of the Devonian sandstones, in which he detected various characteristic fossil shells; but if doubts be entertained whether the quartz-rocks of the Andes may not be of Upper Silurian rather than of Devonian age, there can be no hesitation in referring the next deposits in ascending order to the Carboniferous or true Upper Palæozoic group. At numberless places, limestones have been observed charged with well-known Carboniferous fossils. Several of them, as Productus Cora, Spirifer striatus, Athyris Roissyi, &c., are specifically identical with forms that characterize the strata of this era in Europe and other parts of the globe. As these rocks are associated with, or followed by, accumulations of coal, the general relations of this series are clearly Carboniferous.

We now know, therefore (and the recent explorations in California, Oregon, &c., have confirmed the view), that sedimentary deposits of Silurian, Devonian, and Carboniferous age constitute some of the loftiest ranges and metalliferous plateaux of the American Continent. These were, in ancient times, penetrated by granites, porphyries, trachytes, and other eruptive matters; and in the modern era they form, in some localities, the seat of active volcanic forces. In the sequel it will also appear (see Chapter XIX.) that not merely the Palæozoic, but the Secondary deposits up to the Cretaceous inclusive, sometimes, indeed, even to Tertiary formations, have been so strikingly metamorphosed as to resemble much more ancient rocks, and occasionally have been traversed by auriferous veinstones in the coast-ranges of California §.

To bring, however, the older formations of America into accurate parallel with those of Europe, we must quit the chain of the Andes and the high grounds of Mexico, and turn to British North America and the vast territories of the United States. In large portions of those regions the older strata have been comparatively exempted from igneous disturbances, and geologists have been able to demonstrate the order of succession to be the same as that of which numerous proofs have been recited in the preceding pages.

The great fundamental 'Laurentian system' of Logan, on which all the other sedimentary deposits repose, extends westward to the Lakes Winnipeg and Superior, and, crossing the St. Lawrence at the Thousand Islands, reappears in the Mountains of Adirondack, in the State of New York. Just as the oldest gneiss of the north-western coast of Scotland (see diagram, p. 169) is the foundation-mass of all the rocks of the British Isles, so on a much grander scale is it the oldest rock of the vast western continent. Divided into two masses, the lowest and by far the largest of these, in which the Eozoon has been found, has been noticed in the First Chapter of this volume. For the wide spread of the Lower Laurentian in British North America, the reader is referred to the admirable and clear map published by Sir W. Logan in the 'Report of Progress of the Geolo-

* In the admirable work on South America, by Mr. Charles Darwin (1846), the only Palæozoic fossils alluded to are those of the Falkland Islands (Upper Silurian? and Devonian), though it is probable that some of the clay-slates &c. in the chain of the Chilian Andes, to which he adverts, are of older age.

† Römer, 'Texas, und die physischen Verhältnisse, &c.,' 1849.

‡ See Cordier, 'Rapport à l'Académie Royale des Sciences sur les résultats scientifiques du Voyage de M. Alcide d'Orbigny dans l'Amérique du sud, pendant les 8 années depuis 1826 jusqu'à 1833,' 1842.

§ See Whitney's 'Geol. Survey of California,' 1866.

gical Survey of Canada,' 1865. The relations of all the Palæozoic rocks, from that fundamental gneiss upwards, are therein so clearly developed, even upon a small scale, as to render that map worthy of the admiration of every geologist; for in it twenty-five divisions of those ancient rocks are described with clearness and precision *.

Like the venerable Scottish gneiss, the Laurentian of North America is also unconformably surmounted by hard sandstones, conglomerates, and schists (with limestone and chert), which, attaining the vertical dimensions of about 12,000 feet on the north shore of Lake Huron, have been termed 'Huronian.' This Huronian group or system which has been paralleled by Logan with the Cambrian or Longmynd rocks of Britain, is covered transgressively by the lowest of the fossiliferous bands of the Lower Silurian or Potsdam sandstone (c^1 of Section, p. 169).

For the present we may leave the consideration of those other crystalline rocks which form a broad and long zone, ranging from S.S.W. to N.N.E., along the seaboard of the United States, and extend into Canada and the British Colonies of Nova Scotia, Newfoundland, and New Brunswick. Now, although in geological maps of North America† these rocks have been hitherto laid down under the same colour as those of the Laurentian system, they are essentially distinct from the old gneiss and its associates, and are, as will presently be shown (at least in several parts), nothing more than highly metamorphosed Lower Silurian strata, thus affording another analogy to the rock-masses of the north-western Highlands of Scotland already described (p. 163 *et seq.*).

It is on the western flank of the Appalachian chain, and to the south, north, and west of the Laurentide Mountains, that the Palæozoic formations are best exhibited. They consist of Lower and Upper Silurian, Devonian, and Carboniferous rocks, and are repeated in broad undulations, forming basins of a grandeur and extent unknown, as yet, in any other part of the world excepting Russia. In this way they occupy large portions of the southern and western States—Alabama, Tennessee, Arkansas, Missouri, Illinois, Indiana, Iowa, Minnesota, and Wisconsin. Such deposits range, too, along the southern side of the great chain of lakes, and are spread over extensive tracts of New York, Pennsylvania, Maryland, and Virginia, where their stratigraphical features have been elaborately worked out, and their organic remains described, by many distinguished American geologists.

These authorities have honoured my labours by including the lowest of these great masses of fossiliferous rocks in the Silurian system; whilst all my cotemporaries ‡ who have gone from Europe to explore the United States, or

* This work is the result of the labours of the Geological Surveyors of Canada, namely Logan, A. Murray, T. Sterry Hunt, and E. Billings, assisted, as regards the adjacent parts of the United States, by Professor James Hall, and in the adjacent British Colonies by Principal Dawson, Professors James Robb, J. B. Jukes, and others.

† The maps of Lyell, Marcou, and others, which have represented these eastern crystalline stratified rocks, with their various intrusive or igneous rocks, whether granite, porphyry, or greenstone, &c., under the same Primary colour as the Laurentide Mountains, must now undergo great modification. The statement made in the first edition of this work (p. 410) is also incorrect.

‡ See Bigsby, Trans. Geol. Soc. Lond. ser. 2. vol. i., and Quart. Journ. Geol. Soc. vols. viii., xiv., xv., &c. Featherstonhaugh, Reports on the Countries between the Missouri and Red Rivers, and of Wisconsin, &c., Washington, 1835–36 [my old friend Mr. F. first made known to me the existence of the Silurian series in the United States]. Lyell, Travels in North America, with general map, 1841–42: London, 1843. Lyell's Geological Manual, 3rd ed. p. 351. Castelnau, Système Silurien de l'Amérique Septentrionale. Paris, 1843. De Verneuil, Bulletin de la Société Géologique de France, 2nd ser. vol. iv. 1847. Richardson, Narrative of an Arctic Searching Expedition, 2 vols. London, 1851. Logan, Geological Survey of Canada; Reports to Legislative Assembly, and maps. Logan and Salter on the Rocks of Lower Canada, Brit. Assoc. Reports, 1852, p. 59; Quart. Journ. Geol. Soc. Lond. vols. ix. &c. Ferdinand Römer, Texas und die physischen Verhältnisse des Landes: Bonn, 1849, with geological map. Desor, Bull. Soc. Géol. Fr. ser. 2. vol. ix. p. 342. Jules Marcou, Geological Map and Description

the adjacent territories, have recognized Silurian rocks, both Lower and Upper, followed by deposits of Devonian and Carboniferous age *. In the Canadas, where Bigsby and others were his precursors, Logan, the Director of the Geological Survey of that great Colony, has mapped enormous tracts both of Lower and Upper Silurian rocks; whilst Richardson, triumphing over all the obstacles of the inclement North, has followed Silurian limestones along the western flank of the gneissic chain from Lake Winnipeg to the mouth of the Mackenzie River. The latter has also shown to how great an extent these strata wrap round the huge crystalline nucleus of North America, and form the edges of the continent towards the Arctic Sea. In many of the Arctic islands, too, Upper-Silurian fossils have been detected by the skilful navigators who have sailed in search of the lamented Franklin.

Let me first allude to some of those tracts which, through the labours of geologists in the United States, have been rendered classical in our science, and where the types of comparison have been sedulously and accurately described †.

Palæozoic Rocks of the United States.—The State of New York presents a noble series of Palæozoic deposits, as laid open on the banks of many rivers. By the examination of these natural sections, the geologists of that great State have been enabled to describe a detailed order which is remarkable for its symmetry and unbroken condition from the base of the Lower Silurian to the Coal-measures inclusive, the whole being generally arranged in slightly inclined and conformable strata ‡:—

1. *Silurian Rocks.*—The local subdivisions (about eighteen in number, and of very unequal dimensions) of which the Silurian system, so admirably described by Mr. James Hall, is composed in the State of New York are compared with their European equivalents in a Table which follows (p. 446). Independent, however, of these numerous subdivisions, the lower portion of the series has been admitted by American authorities to be divisible, as in Europe, into two groups, each characterized by peculiar fossils. Thus, from the 'Potsdam Sandstone,' or base of the whole fossiliferous series, up to the slates and arenaceous schists of the Hudson-river Group, overlying the Trenton Limestone, the mass so composed represents the Lower Silurian. In this view, de Verneuil, Logan,

of the United States and British North America: Boston, 1853. This work contains a list of writers on American Geology. Lastly, the numerous books and memoirs descriptive of the geological researches both of the State-Geologists and of the Explorers of the great western territories and the passes of the Rocky Mountains; as well as the reports of the Arctic voyagers.

* It was my anxious desire to visit the United States and the Canadas in 1858, when illness prevented the enjoyment and instruction I had promised myself. As, however, my place was taken by my associate Ramsay, whose acquaintance with the British Palæozoic rocks is as extensive as it is accurate, I was fortunately enabled, through his communications, not only to correct several errata in the first edition, but to bring the older formations of America into a much more accurate parallel with our own deposits than could otherwise have been attempted. This will be specially shown by a comparison of the Silurian and Devonian rocks of America and Britain, in a Table at page 446.

† My cotemporaries in America, whose labours I highly estimate, will readily understand that in a work which is limited to the general history of Palæozoic rocks, and specially those of Europe, I have no space to render justice to the numerous able writings which treat of those tracts of the United States or the British Colonies where such rocks are little developed. Thus the works of Hitchcock, whose description of the structure of his native State, Massachusetts, with its accompanying map, are models of geological monography,—of Dana, whose insight into the natural history of Zoophytes, and whose philosophic reflections on the outlines of the earth, have secured for him a wide reputation,—and the various contributions to the excellent 'Journal' of my friend the late Professor Silliman,—must now be passed over, although, if general geology were my object, they would be eagerly appealed to. Nor will the reader find in the text any allusion to the labours of some authors who have been highly useful in building up the now well-established series of the older formations, such as Maclure, Eaton, Troost, Emmons, Perceval, Vanuxem, Conrad, Jackson, Foster, Thompson, Whitney, and others. The few works above referred to are necessarily those in which the authors have dilated on the subjects which are specially treated of in this volume—namely, comparative views of Palæozoic Geology.

‡ The Synoptical View of the Mineralogical and Fossil Characters of the Palæozoic Strata of the State of New York, by Dr. Bigsby, in the Quart. Journ. Geol. Soc. vol. xiv. pp. 335 & 427, and vol. xv. p. 251, is about to be followed by an inestimable work, the 'Thesaurus Siluricus.'

Bigsby, Ramsay, Dana, Billings, and others agree with Hall * and the United States' geologists.

In the lowest of these deposits, at Potsdam, a small Lingula (L. antiqua, Hall) was, for a long time, the only fossil known except Fucoids and abundant traces of marine Worms (Scolithus linearis). Similar vertical Annelide-burrows have been mentioned (p. 40) as occurring in the Stiper Stones of the typical Silurian tract, and are equally common in the quartz-rock of Durness †, in Sutherland, which underlies the limestone with American types of Mollusca (see p. 165). The parallel, therefore, between these British and Transatlantic zones seems to be complete.

Footprints of a large animal were discovered in rocks of a similar age in Lower Canada, on the south bank of the St. Lawrence, above Montreal. At first they were supposed to have been made by the feet of a Chelonian Reptile; but a further examination of numerous casts taken from the footmarks, and brought to England by their discoverer Logan, led Professor Owen to refer them to Crustaceans—a class of animals commonly met with in Silurian rocks. This view being now adopted, we have evidence of a great protozoic Crustacean, possibly not unlike the giant Pterygotus described in an earlier Chapter (p. 162), though it may prove to have been more like a Trilobite ‡. The Lower-Silurian fossil, Cruziana, so well known in Britain, France, and Spain, also occurs in this lowest zone §.

The most marked mineral distinction of the rocks which immediately lie upon this true Silurian base from those of like age in Britain is the much greater prevalence of limestone. A formation called the 'Calciferous Sand-rock,' which has been paralleled with the crystalline limestone of Sutherland (p. 165), and which in Canada is a dolomite ||, is succeeded by the Chazy, Sillery, and other Limestones, mainly equivalent to our Llandeilo rocks; and they are followed by the great Trenton Limestone with its base of Black-river and Bird's-eye Limestones, and its overlying schists (Utica Slate and the Hudson-river Group). In the lowest of the great calcareous masses (the Chazy Limestone) the peculiar molluscous genus Maclurea (see the figures, pp. 165 & 197) is found, together with some Corals, Polyzoa, and a few Trilobites (Illænus, Asaphus, &c.).

The succeeding calcareous beds (Bird's-eye ¶ and Black-river Limestones) forming the base of the Trenton Limestone seem to partly represent the Caradoc and Bala rocks of Britain, though, as will be shown in the Table, they enclose a larger and more mixed suite of Lower-Silurian fossils. They contain many enormous Orthocerata, the singular Cephalopod genus Gonioceras of Hall, large Lituites, and several Univalve Shells (Murchisonia, Scalites, &c.), besides many species of Orthis and Leptæna, including Leptæna sericea, with other Brachiopods.

The rock into which these beds pass, or the Trenton Limestone, is chiefly, as regards its fossils, a fuller development of the last-mentioned deposits, the number of Trilobites, Gasteropods, Brachiopods, and Crinoids being vastly in-

* Lyell took the same view in his 'Travels in America,' and also in the early editions of his 'Manual of Geology;' and I cannot but regret that in his recent works he has in part abandoned it, now that all the explorers of these ancient rocks of America have supported my classification.

† Mention of the occurrence of Scolithus in the Lower Quartz-rock of Assynt was inadvertently omitted at page 166. The Scottish specimens are described and figured in the Quart. Journ. Geol. Soc. vol. xv. p. 368, pl. 13. figs. 29, 30.

‡ See reduced figures of the Protichnites (Owen) in the Report Geol. Canada, 1863, p. 104; and of Climactichnites (Logan), ib. p. 107.

§ Principal Dawson has shown that such fossil bodies as Cruziana (Rutophycus &c.) may be due to the burrowing of some Limuloid Crustaceans. Professor Rupert Jones has suggested that both Protichnites and Climactichnites have been formed by the great Lower-Silurian Trilobite,—the former being tracks, the latter superficial burrows. See page 201, *note*. Professor Dana also alludes to these Potsdam tracks as having been caused by Trilobites.

|| See Logan's 'Report Geol. Canada,' p. 110.

¶ So called from the numerous specimens of Phytopsis cellulosa which stud the beds and look like eyes.

creased. Besides the large Isotelus gigas, the characteristic fossil of the stratum, Trinucleus concentricus occurs, with the genera Cheirurus (Ceraurus of Green), Lichas, Phacops, and Calymene, all of different species from those of England; but among the Shells, Orthis striatula, O. biforata or lynx, O. porcata (occidentalis, Hall) (Foss. 36. f. 5. p. 193), and Bellerophon bilobatus (Pl. VII. f. 9) are Lower-Silurian fossils, characteristic of the same rocks in Britain, Scandinavia, and Russia. The geological position of this limestone is maintained, too, by the presence of numerous species of Lituites, Orthocerata, and large-plaited Orthides, which resemble those of Europe without being identical. Such, for example, are the two large-plaited species, Orthis pectinella and O. tricenaria, which represent the British forms O. flabellulum and O. Actoniæ (Foss. 35. f. 1, 2. p. 192), and yet are perfectly distinct.

The Trenton Limestone is overlain, throughout a considerable tract in North America, by the Hudson-river Group, at the base of which lie the Utica Slates, full of their characteristic Graptolites. These are covered by, and often pass into the schist and sandstone of the Hudson-river Group, also containing many Graptolites with other fossils, and now regarded as part of the American equivalent of the Caradoc or Bala formation *.

The conglomerates and sandstones of Oneida and Medina, which succeed, are believed to be the representatives of the Lower Llandovery rocks of Britain; and, like them, they may, according to my view, be classed as the uppermost part of the Lower Silurian rocks. Though containing few fossils in the continent of America, beds occupying the same position in the large Island of Anticosti, at the mouth of the St. Lawrence, are charged with Shells which have led Sir W. Logan to refer them also to this date †. Besides Pentameri, they there contain the following Silurian types—namely, Leptæna sericea, Orthis striatula, and Strophomena alternata, with the remarkable elongate Coral (?), Beatricea of Billings ‡.

According to Hall, Logan, and most American authors, as well as Dr. Bigsby, the Clinton Group has been considered the base of the upper division in the United States. It is characterized by the typical Pentamerus oblongus, which, as in England, is never found in any of the succeeding strata.

The same authorities subsequently grouped these rocks containing Pentamerus oblongus, and their inferior sandstones, as 'Middle Silurian;' for, like the Llandovery rocks, they essentially occupy the central part of this natural system. For general purposes of classification, I prefer, however, to adhere to

* M. de Verneuil was the first European geologist who, having examined the collections and visited the localities of the American fossils, successfully compared them with those of our continent. See his most instructive memoir, Bull. Soc. Géol. Fr. 2nd ser. vol. iv. p. 646. The Lower Silurian had not then been subdivided as it now is (see Table, p. 446).

† See Geological Survey of Canada, Report of Progress 1853 to 1856 inclusive, Toronto, 1857, p. 248. This volume, with its accompanying illustrations and book of maps and plans, is highly instructive, and does infinite credit to the Canadian Survey. It makes great additions to our acquaintance with the physical geography and geology of large tracts never before mapped, as examined by Sir W. Logan and Mr. Alexander Murray. The report on the wild and unexplored large island of Anticosti by Mr. James Richardson, the descriptions of the Canadian fossils by Mr. E. Billings, and the reports on the minerals and mineral waters of the region by Dr. T. Sterry Hunt are all excellent. Sir W. Logan and his associates divide the Lower Silurian into seven deposits, viz. Potsdam Sandstone, Calciferous Sand-rock, Chazy Limestone, Bird's-eye and Black-river Limestones, Trenton Limestone, Utica Slate, Hudson-river Group. Subsequently he has indicated the interpolation of the Quebec group between the Calciferous Sand-rock and the Chazy Limestone, as will presently be shown in a description of these rocks in Canada. Then follows the Anticosti or Middle Silurian group, succeeded by Upper Silurian, Devonian, and Carboniferous (Report, p. 248). The still more comprehensive 'Report' of 1863, with its Atlas of Maps and Sections, completes the exposition of these remarkable labours of the Survey to that date.

‡ Specimens of this fossil, from six to fifteen feet long, were at first supposed to be Sea-weeds; but Dawson, Chapman, and Billings regard Beatricea as a 'Rugose' Coral (Canad. Natur. and Geol. new ser. vol. ii. p. 405). Mr. Salter believes that it may be a gigantic Annelide-tube, allied to Cornulites; its cellular structure leads him to this view. Amphitrite has a thick shelly tube some feet in length.

the simple terminology of Lower and Upper Silurian,—grouping the Lower Llandovery rocks with the former, and the Upper Llandovery with the latter division (see Chapter V.).

This method is, it seems to me, preferable, because this central group, which unites, by its fossils, the inferior and superior masses, is often not rich in organic remains, and in some countries (as in Bohemia) cannot be easily separated from the subjacent and overlying deposits.

The Clinton Group is immediately followed by the Niagara Shale, which in all respects resembles the well-known Wenlock Shale of Britain; whilst the chief or central mass of the Upper Silurian rocks in North America is that called the Niagara Limestone, which unquestionably represents the Wenlock and Dudley Limestones of England, as well as of Gothland in the Baltic. These rocks appear to contain a greater number of fossils identical with those of Europe than do the Lower Silurian strata of the same districts. Among them are Calymene Blumenbachii, Homalonotus delphinocephalus, Bumastus Barriensis, Rhynchonella cuneata, Rh. Wilsoni, Pentamerus galeatus, Orthis elegantula, O. hybrida, Orthoceras annulatum, Eucalyptocrinus decorus, and Bellerophon dilatatus. (See Chaps. IX. and X.) Some of the large European Corals also prevail—those which may have been capable of forming reefs, as Favosites Gotlandicus, F. alveolaris, and the Chain-coral. There are also many peculiar species: indeed Professor Milne-Edwards has shown that out of a considerable list of American Corals few are really identical with those of Europe.

The lower formations of the next overlying or Helderberg division, up to the higher Pentamerus-limestone inclusive *, constitute (according to de Verneuil) the probable equivalents of the Ludlow rocks. The much greater abundance of calcareous matter in the higher part of this division than exists in our own Ludlow rocks, and the absence of that muddy and sandy matrix which characterizes those strata in Britain, have necessarily given to the whole group more the character of the Wenlock formation,—a feature which, as we have already seen, is dominant in Gothland, Russia, Bohemia, &c.

2. *Devonian Rocks.*—The base of the Devonian rocks of the United States has been placed lower than it was in the earlier comparisons with European deposits. Seeing that a mass of sandstones and conglomerates had there been called 'Old Red Sandstone,' it was natural, in the first instance, for geologists to suppose that the Devonian series in North America did not descend far beneath this rock. Hall and others, however, have long since agreed with de Verneuil in considering the Oriskany Sandstone to be the true Devonian base; for this rock contains Spirifer macropterus, Pterinea fasciculata, and Pleurodictyum problematicum, all species of the lowest Devonian of the Rhine, Belgium, and France, which are unknown in any Silurian rock (see Table facing p. 405). The lowest Devonian rock in America is therefore precisely similar to its type in Western Europe.

A further reason for placing the Oriskany Sandstone at the base of the Devonian rocks of New York consists in the clear indications of its having been deposited in excavations in the inferior stratum, as explained by Mr. J. Hall. This phenomenon marks a previous denudation, and the commencement of a new series †.

* These consist, in ascending order, of the Onondaga-salt Group, the Water-lime Group, Lower Pentamerus-limestone, Delthyris Shaly Limestone, Encrinital Limestone, and Upper Pentamerus-limestone.

† The subject of the succession of the North-American deposits, whether in the State of New York or in the adjacent British territories, has been clearly illustrated by Dr. Bigsby, one of the most able and energetic explorers of those regions in former years. The general succession is that given in the Table at the end of this Chapter. Di-

Judging also from the included organic remains, such as Goniatites identical with those of the Duchy of Nassau in Germany, Murchisonia bilineata, Productus subaculeatus, Athyris concentrica, and other fossils, M. de Verneuil further included in this group the Chemung Rocks, the Hamilton and Marcellus Shales, and the Cliff Limestone of Ohio and Indiana (Corniferous and Onondaga Limestones). The last-mentioned deposits contain fossil Fishes analogous to those of Scotland, besides some characteristic Devonian Shells. Again, the occurrence of an Ichthyolite of the genus Asterolepis, associated with forms of Spirifer, in the Schoharie Grit of New York, necessarily placed that rock also in the Devonian series.

As fossil Fishes have usually proved the most exact indicators of the age of all supra-Silurian rocks, the occurrence, in these Devonian strata, of Asterolepis, a genus common in the central Scottish beds of this epoch, and the intermixture of other Ichthyolites identical with those of the same country, with Shells of the Eifel and of Devonshire, are to me the most convincing proofs that these diversified deposits in North America (like those of Russia, the Rhenish Provinces, and Devonshire) are simply equivalents, in time, of the very grand British deposits called Old Red Sandstone; for it must be recollected that under this term, and particularly in the north-east of Scotland, are included conglomerates, sandstones, grey schists, limestones, and flagstones, as well as sandstones of both red and whitish-yellow colours—in all, several thousand feet thick (see Chapter XI.).

In one portion of the Canadas, Sir William Logan has estimated the Devonian rocks to have a thickness of 7000 feet; and in the State of New York they occupy a more considerable space than the Silurian; but this Devonian series of micaceous sandstones and schists thins out as it passes westwards into the States of Ohio, Indiana, and Kentucky, and disappears entirely on the Mississippi, where the Carboniferous strata repose at once on those of Silurian age.

3. *Carboniferous Rocks.*—The Carboniferous rocks are, as is now well known, developed in the United States in basins of vaster dimensions than in any part of Europe. By the aid of their included fauna and flora, the American strata are absolutely identified with the deposits of like age in Europe. Great masses of sandstone and schists, once considered to be Devonian, and so coloured in early geological maps of the United States, have been shown by M. de Verneuil, from their imbedded fossils, to be of Carboniferous age. These masses, which are of considerable thickness, form the true base of the Carboniferous rocks of North America, and are probably the equivalents of much of the Yellow Sandstone of Ireland, as well as of certain rocks in Westphalia, which were formerly classed with the 'grauwacké,' but are now ascertained to belong to the Lower Carboniferous beds of the Rhenish Provinces (see p. 402).

Next follows the Carboniferous Limestone (Mountain-limestone of early English

viding the Silurian rocks into Lower, Middle, and Upper, Dr. Bigsby makes also a triple division of the Transatlantic Devonian rocks, analogous to that of the European. In addition to many important inferences respecting the distribution of Palæozoic life, Dr. Bigsby infers that "the Silurian and Devonian systems of New York belong to one connected period, being the products of successive and varying Neptunian agencies, operating in waters which deepened westward from the Atlantic side, and southward from the Laurentian chain on the north. These Palæozoic groups pass one into the other by gradual mineral and zoological changes, there being a nearly perfect conformability and a considerable community of fossils. The chief break is at the Oriskany Sandstone (base of the Devonian), there being no break of like importance at the period of the local Oneida Conglomerate (Middle Silurian). A division of the Silurian and Devonian systems, each into three stages, is based on the change of sediment and on the fossil contents. The Middle Silurian stage is a period of especial transition, from the coarseness of some of its sediments, and from their alternations, as well as from the organic poverty prevailing." (See the abstract of his memoir in the Proceedings of the Geol. Soc. of London, No. 5, Session 1857–8; also his memoirs in full, in the Quart. Journ. Geol. Soc. vols. xiv. and xv.)

geologists), which, whilst it encircles the great Coal-fields of Michigan, Illinois, and the southern part of the Appalachian Coal-field, is wanting in Pennsylvania and Ohio. This rock contains many varieties of Productus, viz. P. semireticulatus, P. Cora, P. punctatus, &c., with species of Bellerophon, Goniatites, Spirifer, and Terebratula, known not only in Britain, but also in many parts of Europe and Asia *.

The Foraminifera, a group of which few have been determined in the Palæozoic strata, have also a very wide range; for the very same species (Fusulina cylindrica) which so abounds in Southern Russia is also found in the Carboniferous rocks of North America.

The lamelliferous 'Rugose' Corals (Zaphrentis, Lithostrotion, &c.) are not absent; but they are chiefly of species distinct from those of Europe; and some of the forms of this group most characteristic of the old Continent (Syringopora, Amplexus, &c.) appear to be absent from this series in the new.

It is unnecessary here to dilate upon the vast overlying productive Coal-fields, which, occupying distinct basins of stupendous dimensions, have been described by numerous native authors (Rogers, Owen, &c.), and have been well depicted by Lyell and Dawson. But I must advert to the great similarity—nay, identity—between the Plants of these vast Coal-deposits and those of Europe. It is a feature highly worthy of the special notice of geologists, that at this early period the same species of gigantic Plants were spread over an enormous area of the earth's surface, which, from the nature of its vegetation, must therefore have been under the same conditions of atmosphere and climate, if not of physical outline. This specific agreement is indeed curiously at variance with the sharp distinction between the existing floras of North America and Europe (see Lyell's Travels in North America).

This short notice of the development of the earlier fossiliferous rocks in the United States cannot be concluded without a special allusion to the important additions made to this branch of knowledge by certain American authors. The researches of Prof. James Hall, as recorded in his work on the Palæontology of the State of New York †, have shown that, with increased observation, there is great difficulty (except for short distances and in limited tracts) in drawing an arbitrary line between the lower and upper divisions of the Silurian system. The thinning out or the thickening of the subdivisions termed Medina Sandstone, and Clinton and Niagara Groups, is accompanied by just the same kind of intermingling of fossils which has been observed, though to a greater extent, in the British Isles. Several species, says Prof. Hall, known before only in the lower are now found at the base of the higher group. But, before we can speak of the number of species which range from the Lower into the Upper Silurian, all the older fossils of North America must be examined and compared. Even in the one State of New York, however, we learn that Bellerophon bilobatus, Orthis lynx, Strophomena alternata, and some other forms common to Europe and America, and abundant in the Lower Silurian, occur in the higher part of the Medina Sandstone, which in that country is intimately united with the upper division.

The same elaborate work of Prof. Hall must be consulted for the figures of many species of Fucoids common to the Medina Sandstone last noticed and the associated Clinton Group. Numerous tracks or trails of Gasteropods and Crustacea also occur, indicating that the sediment so marked was accumulated in shallow water, or under ebbing and flowing tides, and on sloping shores. To

* The Cestraciont (Cochliodont) Fishes of Illinois, discovered by Dr. B. Shumard, have been described by Dr. Joseph Leidy (Trans. Amer. Phil. Soc. vol. xi. p. 687).
† Nat. Hist. New York, Part VI. Palæontol. vol. ii. 1852, p. 3.

the consideration of these data we shall return in the last Chapter, in explaining the conditions under which some of the oldest marine deposits were formed.

Notice must also here be taken of the survey of the extensive territories of Wisconsin, Iowa, and Minnesota, by which the late Dr. Dale Owen has extended true Palæozoic classification on a very broad scale. The area examined by this author and his associates, Drs. Norwood and Shumard, is much larger than Great Britain; and by far the greater portion of its subsoil is referred by them to the Silurian, Devonian, and Carboniferous rocks *. This magnificent region is traversed by the Mississippi in its descent from the boundaries of British America and Lake Superior, and is included between that mighty river and its huge affluent the Missouri. Surrounding and supporting an enormous Carboniferous tract, the older primeval rocks rise out successively in very slightly inclined positions. The results of this survey which have most interested me are the discovery of two bands containing Trilobites, in the lowest Silurian sandstone, and the fact that the organic forms of these beds are considered to be referable to the 'Zone Primordiale' of Barrande as it exists in Bohemia and Scandinavia, or in the 'Lingula-flags' of Britain (see pp. 41, 350, 372). We thus obtain proofs that the earliest Silurian deposit of America, whether in the condition of sandstone at Potsdam and in the region of the Mississippi, or as the metamorphic and slaty rock of the eastern seaboard of the United States, does really contain, as in Europe, the first clearly recognizable fossil animals which pertain to this series of life †.

Specimens of a very large species of Paradoxides have been found by Professor W. Rogers in a band of siliceous and argillaceous slate, ten miles to the south of Boston, which is enclosed between great masses of igneous rocks. A longer and broader species of the same genus has been sent from St. John's, Newfoundland, to the Bristol Institution; and a species of Conocephalus has been found in the Sandstone of Georgia ‡. A large portion of the crystalline masses which flank the coal-fields of the British Colonies of New Brunswick, Nova Scotia, &c., have also proved to be metamorphosed Silurian strata, thus largely extending the structural analogy between North America and the Highlands of Scotland.

The Lower Silurian, so termed and laid down on their map by Dale Owen and his associates, consists, in its inferior portion, of pebble-beds, grits, and sandstone § of red and greenish colours, which, as they range upwards, begin to alternate with magnesian limestone. Then, in ascending order, the limestones with green grains (resembling some of the Russian Lower Silurian, p. 355) predominate, and are in parts oolitic, in other parts quartzose and cherty. Again, sandstones, usually white, recur, and are surmounted by shelly beds which, in Iowa and Wisconsin, represent the Trenton Limestone of New York and the Llandeilo formation of Britain.

The Upper Silurian rocks are poorly represented, in these unfrequented tracts, by what Dr. Dale Owen termed the 'Upper Magnesian Limestone,' consisting of

* This work, following so many other valuable publications, is a proof that the Senate, as well as the State Governments, has justly appreciated the value of the application of geological science as a prelude to the settlement of a new country.

† See 'Proofs of the Protozoic Age of some of the Altered Rocks of Eastern Massachusetts,' by Professor W. B. Rogers, Proc. American Academy of Arts and Sciences, vol. iii. 1856; and Proc. Boston Nat. Hist. Soc. vol. vi. pp. 27, 40, &c.

‡ See Mr. Salter's account of these fossils, Quart. Journ. Geol. Soc. vol. xv. p. 551, &c.

§ The Trilobites of this, the lowest Silurian stratum in America (the Potsdam Sandstone), are termed, by Dr. Owen, Dikelocephalus, Lonchocephalus, &c. Judging from the drawings, these genera seem to be referable to the same group as Paradoxides. They are associated with Fucoids and Lingulæ. After studying the work of Dr. Dale Owen, M. Barrande is convinced that the author has established the proof of the existence in the New World of the 'Primordial' Silurian zone of Bohemia and Sweden, and the same order of succession upwards from it into the mass of the Silurian strata as in Europe. In this view M. de Verneuil coincides.

beds with Corals and Pentameri, all traces of the equivalents of the Ludlow rocks being absent. The Devonian period, however, is clearly defined, particularly by its broad-winged Spirifers; whilst the Carboniferous Limestone is much expanded, and a large portion of it has been distinctly referred to the 'Yoredale series' of Phillips in Yorkshire. The western explorations of Captain Stansbury to the Mormon Territory and the Salt Lake of Utah have further shown us that strata charged with Carboniferous fossils extend to the edges of the Rocky Mountains, those great northern extensions of the Andes.

Palæozoic Rocks of British North America.—The oldest of these masses (the Laurentian) has been described in the beginning of this work. The next in ascending order, the Huronian, or the lower copper-slates and sandstones of the great lakes, have, to some extent, the same structure as considerable portions of the Longmynd or Bottom rocks of the Silurian region *. They are, in truth, defined as such by Logan, being termed by him the equivalents of the 'Cambrian,' so defined by De la Beche, Ramsay, and the British Government Surveyors, as well as by myself. In England and North Wales these old slaty rocks contain little or no limestone; but in North America they are largely interlaced with it.

Again, whilst in Great Britain and Germany these Cambrian rocks are succeeded conformably by the Lower Silurian, they have been severed therefrom in America, as in France and Ireland, by a grand dislocation. In thus appealing to the conditions in different countries, we learn the impracticability of classifying sedimentary deposits according to age by the lines of fracture and dismemberment alone. In making this statement, however, I do not prejudge the views of my eminent friend M. Élie de Beaumont, concerning the directions of mountain-chains as typical of certain epochs. This topic, requiring much illustration, would lead me away from the special objects of this work.

In the last few years great advances have been made in unfolding the features and in fixing the eras of the formation and dislocation of all the Palæozoic rocks of Canada; and I am most grateful to Sir W. Logan, the Director of the Geological Survey of that great Colony, for having furnished me with the following information:—

"1. *Silurian Rocks.*—The Silurian rocks of North America present in their lower portion very marked differences in different areas. This the Geological Surveyors of Canada have explained by showing that the Lower Silurian rocks of the New York system represent a portion only of the great succession of sediments which in the earliest of those periods were deposited in the great ocean surrounding the Laurentian and Huronian nucleus of the present American continent. Oscillations of this ancient land permitted the spreading out on its surface of those sheets of sediment which constitute the Lower Silurian formations of New York and Central Canada: but between the periods when the Potsdam Sandstone and the Chazy Limestone were formed, a rapid continental elevation and subsequent gradual depression allowed a great intermediate accumulation of deposits, which are now displayed in the Green-Mountain range on the one side of the ancient nucleus, and in the metalliferous series of Lake Superior on the other, while they are necessarily absent in the intermediate New York series.

"A great dislocation along the eastern line of the ancient gneissic continent commenced at a very early date in the Lower Silurian period, and gave rise to the division which now forms the eastern and western basins. The western basin includes the strata which extended over the surface of the submerged continent, together with the Pre-Chazy rocks of Lake Superior; while the

* For a complete *résumé* of the relations of the Huronian and Cambrian rocks see Dr. Bigsby's memoir in the Quart. Journ. Geol. Soc. vol. xix. p. 36.

Lower Silurian group of the eastern basin presents only the Pre-Chazy formation, unconformably overlain in parts by Upper Silurian and Devonian rocks. The group between the Potsdam and Chazy deposits in the eastern basin has been separated into three divisions; but in the western basin these subdivisions have not yet been defined. In the latter the strata are comparatively flat and undisturbed, while in the eastern basin they are thrown into innumerable plications, a vast majority of which present anticlinal folds overturned on the north-western side. The general sinuous north-eastern and south-western axes of these folds are parallel with the great dislocation of the St. Lawrence, and the undulations are a part of those belonging to the Appalachian chain of mountains. It is in the western basin that we must look for the more regular succession of the Lower Silurian rocks from the time of the Chazy Limestone, and in the eastern, including Newfoundland, for that of the older deposits. It is to be remarked, however, that in the great northern peninsula of Newfoundland, instead of undulations, lines of fracture and dislocation are observed, while the strata are comparatively little tilted; and it has not yet been precisely defined where the limit between the eastern and western basins of that island is to be placed. It seems probable, however, from the recent investigations of Mr. A. Murray, that it will run on the east side of the Laurentian mountains, forming the chief mass of the peninsula just mentioned.

"The succession of the Lower Silurian deposits in North America may be thus tabulated, the palæontological evidence as to the relations of the Upper Calciferous and the Quebec Groups to the formations above and below having been determined by Mr. Billings:—

		Complete Series.	Western Basin.	Eastern Basin.	Newfoundland.
Caradoc	12.	Hudson-river Group	Hudson-river Gr.		
	11.	Utica Slate	Utica Slate.		
	10.	Trent', Bird's-eye, &c	Trenton, B's-eye, &c		
	9.	Chazy Limestone ..	Chazy Limestone.		
Llandeilo	8.	Sillery. } Quebec Gr.	Quebec Group.	Sillery. } Quebec.	Sillery. } Quebec Group.
	7.	Lauzon. } Quebec Gr.		Lauzon.	Lauzon.
	6.	Lévis. } Quebec Gr.		Lévis.	Lévis.
	5.	UpperCalciferous Gr.	....	....	U. Calciferous G.
'Primordial'...	4.	LowerCalciferous Gr.	L. Calciferous Gr.	....	L. Calciferous G.
	3.	Upper Potsdam Gr.	U. Potsdam Group.	....	U. Potsdam Gr.
	2.	Lower Potsdam Gr...	....	L. Potsdam G.	L. Potsdam Gr.
	1.	St. John's Group ...	....	St. John's Gr.	St. John's Group.

"It thus appears that the lower portion of the series is complete in Newfoundland, the upper in New York, and that the divisions 3, 4, and 5 have not yet been recognized in the eastern continental region. The St. John's Group (1) is represented at St. John's, New Brunswick by three thousand feet of black slates and sandstones, whose fauna, described by Mr. Hartt, was correctly referred by him to Barrande's 'Stage c' or 'Primordial' Silurian zone. It there reposes on rocks regarded as Cambrian. The slates of St. John's, Newfoundland, and the Paradoxides-bed at Braintree, Massachusetts, also probably belong to the same horizon.

"The Lower Potsdam Group (2) is represented by several hundred feet of limestones and sandstones on the Strait of Bellisle, by a much greater thickness in White Bay, Newfoundland, and by the slates of St. Alban's and Georgia, Vermont. The Upper Potsdam (3) is that of Wisconsin and Minnesota, represented by the typical Potsdam rock of New York, and is overlain by the

Lower Calciferous Group (4); while the Upper Calciferous (5) is only recognized in Newfoundland.

"The Quebec Group (6, 7, 8) is divided into three parts, named from regions where they are largely displayed. The first or lowest division embraces the limestones and black slates of Point Lévis, Orleans Island, and Phillipsburgh, with their numerous fauna of Trilobites and Graptolites, for the most part identical with those of the Skiddaw Slates. The second or Lauzon division was at first united with the preceding, but has been separated from it on account of its great mineralogical importance and distinctness, it being the metalliferous zone of the Lower Silurian in North America. Magnesian rocks, including dolomites, magnesites, serpentines, diorites, and chloritic and steatitic beds, with micaceous and gneissic strata, characterize this Lauzon division, which is, moreover, rich in copper-ores, chiefly as interstratified cupriferous slates, and is accompanied by the ores of silver, gold, nickel, and chromium. The only fossils certainly recognized in it are an Obolella and two species of Lingula at its summit. It is overlain by the Sillery division, which consists of a great mass of sandstones and conglomerates, 2000 feet thick, interstratified with red and green slates, and so far as yet known destitute of organic remains.

"In a large part of its distribution, the Quebec Group is crystalline and metamorphic; but the characteristic elements of the group are to be found both in the altered and unaltered portions. The Lauzon division, as lately shown by a careful investigation in the field by Sir William Logan, constitutes the Taconic range of hills in Massachusetts and New York, the strata of which are arranged in a synclinal form, and are traceable to a geological place between the Sillery of Berlin Mountain and the black graptolitic slates of Hoosick. The equivalency of the 'Taconic system' of the late Professor Emmons and the Quebec Group has been completely established by the Geological Survey of Canada *.

"In western Canada and New York there is a great palæontological break between the Hudson-river and Clinton formations; but in Anticosti, which is on the north-west side of the great St. Lawrence dislocation, and therefore in the western basin, the Hudson-river band is succeeded by a formation of limestone 306 feet in thickness, from which eighty-six species of fossils have been collected. Forty-one of these occur in the Hudson-river limestone, and eighteen pass upwards. Above this there occurs another formation of limestone 447 feet in thickness, with thirty-nine species, of which eighteen come from below and twenty-three pass upwards. The true Clinton beds succeed, crowded with Pentamerus oblongus. These beds of passage from the Lower Silurian in Anticosti, appear to correspond in horizon with the slightly fossiliferous Oneida and Medina deposits of New York, and, together with the Clinton, Niagara, and Guelph deposits, which graduate into one another, they constitute a Middle Silurian group. In the eastern basin such beds of passage from the Lower Silurian are wanting; and the only portion of the Middle Silurian series that has been met with there is a patch at the Forks of the Chatte River, whose horizon is about the base of the Clinton group.

"In the western basin there is another great palæontological gap between the Guelph formation and the Lower Helderberg Group. In it the Onondaga

* Sir William Logan informs me that the same series can be followed from the States of New York and Massachusetts throughout Vermont into Canada in three main undulations, bounded on the east by Upper Silurian and Devonian rocks. On the west this series, which Dr. Emmons had erroneously placed beneath all the Silurian rocks, is seen to rest upon the Potsdam Sandstone or 'Primordial' Silurian. These facts prove the inapplicability of the name 'Taconic' to the oldest fossil zone in Norway (see p. 353).

formation occurs, the magnesian and saliferous deposits of which, having been unfavourable to the support of life, have rendered the formation nearly destitute of organic remains. In the eastern basin, however, this break is filled up by a series of rocks, on the Bay Chaleur and in the State of Maine, containing a fauna which has as yet been worked out only so far as to prove its absence from Western Canadà and New York, and exhibiting many characteristic forms of the Wenlock and Ludlow fossils, such as Euomphalus rugosus, Bellerophon dilatatus, and Orthoceras filosum. At the summit of the Onondaga formation, in the western basin, is the Water-limestone, characterized by Eurypterus, and above it the Lower Helderberg group. In the eastern basin the Gaspé limestones appear to form a great expansion of this group, and, together with the Bay-Chaleur limestones, are classed as Upper Silurian.

"2. *Devonian Rocks.*—The fauna of the lower Gaspé limestones still bears a resemblance in many of its forms to that of the Ludlow rocks; but the upper present a considerable intermixture of Devonian species; and Psilophyton princeps, a characteristic Devonian Land Plant, has been found towards the summit. This upper part, if not classed as Devonian, must be regarded as beds of passage. In accordance with this and the synchronism of de Verneuil, the Oriskany formation of New York is, in Canadian geology, assumed to be the base of the Devonian rocks. In the western basin this series is separated into several arenaceous, calcareous, and argillaceous formations, each distinguished by its fossils. One of these formations in Western Canada, the Corniferous Limestone, is remarkable as the source, in that locality, of the great yield of petroleum, obtained from fissures which characterize a series of gentle anticlinals subordinate to the great Cincinnati undulation, which separates the Appalachian from the coal-fields of Michigan and Illinois. In the eastern basin the Devonian series is represented in Gaspé by seven thousand feet of sandstones. The organic remains discovered in these rocks are yet too few to authorize their separation into distinct members; but while the lower part contains many fossils identical with those of the Oriskany formation, a species of Rensselæria, identical with or closely resembling R. ovoides which occurs in the limestone beneath, is met with high above the base of the sandstone series. This fact and the constancy in lithological characters of the latter make it probable that this lower portion, at least, of the sandstones is to be classed with the Oriskany Sandstone. From their base to their summit the Devonian rocks are profusely charged with comminuted remains of Land Plants, in the recognized species of which, eight in number, there appears to be little difference throughout. These strata present analogies with the whole series of formations in New York, from the Marcellus Shales to the summit of the Chemung Sandstones, in all of which, according to Dr. Dawson, are found several of the species of Plants that occur in the Gaspé sandstones. The sandstones resemble lithologically those of the Portage and Chemung group of New York; and it may hereafter be found that in this eastern part of the continent the Oriskany fauna, which occurs at their base, merges gradually into that of the Chemung deposit. In the Gaspé sandstones casts of shrinkage-cracks are very common, and root-beds, associated with Psilophyton, occur at many horizons; and on one of the root-beds, near the base, reposes a very thin but regular seam of coal. Both the Gaspé sandstones and the limestones beneath are marked by the presence of petroleum-springs, leading to the expectation that they may give out notable quantities of oil.

"3. *Carboniferous Rocks.*—Carboniferous rocks, as is well known, spread out

in both the eastern and the western basins. In the latter the productive Coal-measures, occupying four separate fields, the Appalachian, the Michigan, the Illinois, and the Iowa and Missouri, cover a greater area than Coal-measures in any other part of the globe. In the eastern basin the Lower Carboniferous Limestone (the Mountain-limestone of England) is wanting; but in the western it either partially or wholly supports all the Coal-measures mentioned, gradually thickening as it spreads westward; while, according to Professor Hall, an Upper Carboniferous Limestone rests upon the Iowa and Missouri or most western Coal-field. None of the Carboniferous rocks enter Western Canada; and in Eastern Canada only a portion of the Bonaventure formation, equivalent to the Millstone-grit of England, presents itself, on the south coast of the peninsula of Gaspé, where it emerges from beneath the Coal-measures of New Brunswick and Nova Scotia, which in the latter province exhibit, at the Joggins, on the Bay of Fundy, a thickness of nearly 15,000 feet.

"In the western basin there is no apparent want of conformity in the whole series of deposits from the base of the Lower Silurian to the base of the productive Coal-measures; but in the northern part of the Illinois Coal-field, the latter overlap the Millstone-grit and Mountain-limestone. In the eastern basin there is a discordance between the Lower and the Middle Silurian, and also between the Devonian and Carboniferous. The undulations, however, which cause these discordances, and which affect the formations from the base of the Lower Silurian to the summit of the Coal-measures, are all in parallel directions, showing that the forces which operated to produce the folds continued throughout the whole Palæozoic period, during the latter part of which their influence extended far into the western basin, reaching across the Appalachian Coal-field, and producing the great Cincinnati anticlinal."

Nova Scotia.—In Nova Scotia, the oldest rocks of the Atlantic coast of this British Colony consist principally of slates and quartzites, equivalent to the oldest slates of Newfoundland, which are known to contain Paradoxides. They therefore represent the lowest portion of the Silurian system. In the southern part of New Brunswick, the researches of Professor Bailey and of Messrs. Mathew and Hall, have disclosed a similar series, which appears in the vicinity of St. John's, and contains species of Paradoxides and Conocephalus. Professor Hind refers to the Quebec Lower Silurian group a large portion of the partially altered rocks of the northern part of New Brunswick underlying the Upper Silurian of that region. The rest of the Lower Silurian series of Nova Scotia is often much metamorphosed, and is the seat of much gold-ore, of which hereafter*.

The Upper Silurian series of Nova Scotia is represented by considerable areas of disturbed and partially altered rocks, which seem to represent the British formations from the Upper Llandovery to the Ludlow rocks inclusive. They differ, however, in several features, from the Upper Silurian of New York and other portions of the great interior of North America, but coincide with the rocks of this age in New Brunswick and Maine, on the eastern side of the great Appalachian line of disturbance †. It is probable that these eastern Upper Silurian areas of North America (says Dr. Dawson) will be found to present characters intermediate between those of the inland area of the continent and those of the Upper Silurian of Western Europe.

* In illustration of these points, see Principal Dawson's Supplement to 'Acadian Geology,' and the Reports on the Geology of Southern New Brunswick.

† See Dawson on Silurian and Devonian Rocks of Nova Scotia, Canadian Nat. Hist. vol. v., and Dr. Honeyman's 'Geology of Arisaig,' Quart. Journ. Geol. Soc. vol. xx.

Devonian Rocks of Nova Scotia and New Brunswick.—An extensive and complicated series of this age has been ascertained to exist in Southern New Brunswick; and Dr. Dawson has recognized an equivalent of the lower member of the series, or the Oriskany Sandstone, at Nectaux in Nova Scotia, where it contains extensive deposits of iron-ore. These rocks do not, however, correspond lithologically either with the Devonian of New York, or with the Gaspé sandstones which represent this period in Eastern Canada. The deposits of the period which elapsed between the close of the Upper Silurian and the beginning of the Carboniferous, though on a large scale as to thickness, would appear in Eastern North America to have little horizontal uniformity over large areas. This feature harmonizes with the fact that the period was characterized by the eruption of great granitic dykes and masses, and also by a luxuriant land-flora indicating extensive terrestrial surfaces. Dr. Dawson has, within a few years, described no less than eighty-two species of Land Plants from the Devonian rocks; and of these probably ten ascend to the Carboniferous system, while two occur in the Upper Silurian. The greater number of the species occur in the Upper Devonian. The genera specially Devonian are principally Psilophyton, Leptophlœum, Prototaxites, Syringoxylon, and Nematoxylon, while the greater part of the species belong to genera well known in the Carboniferous rocks, as Lepidodendron, Dadoxylon, Cyclopteris, Neuropteris, Sigillaria, &c.; indeed nearly all the leading Carboniferous genera are represented *.

Among the important conclusions of Dr. Dawson are the following:—With few exceptions, the generic types of the Devonian and Carboniferous periods are the same, six out of the thirty-six genera only being peculiar to the Devonian deposits. In the ascending order there is always a constant gain in the number of genera and species. That a large part of the difference between the Devonian and the Carboniferous floras is probably referable to different geographical conditions, the land of the Devonian having probably been of a more upland and truly terrestrial character than the swampy flats on which the vegetation of the Coal-period grew. On this head I have already made an allusion to the tracts of the supposed Upper Old Red Sandstone of the North-east of Scotland (p. 270).

For a better acquaintance with these Devonian rocks, so very rich in fossil Plants, and with their great development towards the close of that epoch, the reader must consult the instructive memoirs by Dr. Dawson. I have only to observe that his general conclusions do not materially differ from those which Bronn, Göppert, and Unger have drawn from an examination of the Devonian flora of Europe.

It is interesting to add that the Devonian strata of the vicinity of St. John's have afforded to Mr. C. F. Hartt the only remains of Insects hitherto found in rocks older than the Carboniferous. From a note by Mr. Scudder, in the excellent Report on the southern part of New Brunswick by Professor Bailey, it would appear that fragments of five species have been found, all probably Neuropterous. One is a member of the group Ephemerina, several times larger than any modern species.

North-western and Arctic America.—In taking a general view of the physical structure of the northernmost portion of America, the late Sir John Richardson, the great Arctic traveller, considered that, on the whole, the granitic and crystalline rocks of the central and eastern countries of the Hudson's Bay ter-

* Dawson, 'Flora of Devonian Period,' Quart. Journ. Geol. Soc. vol. xviii. and vol. xix.

ritories (now termed Laurentian) are surmounted by few other deposits on the west and north, except by masses of Silurian age, and young Tertiary strata. In his graphic description of the structure of Canada, Lyell expressed the same opinion. "I seemed," says he, "to have got back to Norway and Sweden, where, as in Canada, gneiss and mica-schist, and occasionally granite, prevail over wide areas, while the fossiliferous rocks belong either to the most ancient or to the very newest—to the Silurian or to deposits so modern as to contain exclusively shells of recent species" *. From the western shore of Lake Winnipeg †, a limestone containing gigantic Orthocerata (allied to those described by Dr. Bigsby and Mr. Stokes ‡ from the Upper Silurian of Drummond Island) and the strange fossil named Receptaculites § was traced in horizontal sheets stretching westwards over four or five degrees of longitude. Though this plateau is separated from the Rocky Mountains by a broad belt of the Prairies of the Saskatchewan, the bed of that river is full of limestone blocks which indicate the persistence of the rock. After crossing Methy Portage, in lat. 56¾°, Richardson again met with extensive calcareous deposits. The fossils which were gathered from this tract (Productus, Orthis, Spirifer, &c.) seem, however, to indicate an ascending order into beds of Devonian and Carboniferous age ‖, particularly in the wide spread of calcareous matter along the Elk and Slave Rivers, and upon the banks of the Mackenzie. Where the last-mentioned river skirts the Rocky Mountains, the limestones, more disturbed than in the Winnipeg basin, occupy, says Richardson, inclined and elevated ridges, the chief of which he considers to be Silurian; these ridges, on the Great Bear Lake and the Coppermine River, abut against granite. In a letter to myself he added, "I believe the strata of sandstone and limestone on the north coast of America to be wholly Silurian, though fossils are scarce. Towards the mouth of the Coppermine River there are, besides, magnificent ranges of trap with ores of lead and copper, including much malachite."

To whatever extent it may be found possible to separate the Silurian rocks which range along the Rocky Mountains into a Lower and an Upper group, it would at least appear, from the specimens which have been collected by our naval explorers employed in the Arctic Expeditions, that the great mass of the most northern rocks belongs to the Upper Silurian group. This is certainly the case, if we judge from the collections made during the voyages of Parry, Franklin, Ross, Back, Austin, and Ommanney, and the private expeditions of Lady Franklin, particularly those of Penny and Inglefield, and the expedition under Sir E. Belcher. The fossils brought home by these commanders and the officers and gentlemen accompanying them have been examined and described ¶ by Mr. Salter; and from his scrutiny it results that the Crustacea and Mollusca are very similar to, and some of them identical with, those of Wenlock, Dudley, and Gothland. Among these occur:—Encrinurus lævis, Angelin; Leperditia Balthica, His.; Pentamerus conchidium, Dalm.; Chonetes lata?

* Travels in North America, 1st series, ed. 1, vol. ii. p. 124.

† The geography and geological structure of the great region of Rupert's Land, watered by the Red, Assiniboine, and Saskatchewan Rivers, have been ably described and mapped by Henry Youle Hind since the publication of my last edition. See the account of his Expedition, published by Longman & Co. in 1860.

‡ Bigsby and Stokes, Trans. Geol. Soc. 2nd ser. vol. i. Similar Orthoceratites were found by Sir W. Logan further to the east, in rocks of Upper Silurian age.

§ Referred by Mr. Salter to the Foraminifera, as a gigantic form allied to Orbitolites, which is seldom found more than half an inch in diameter: but these older representatives of the order were not less than six or seven inches, and of a proportionate thickness! Mr. Billings, however, refers Receptaculites to the Sponges.

‖ A few specimens of the fossils of these rocks are in the British Museum; they are Upper Silurian, Devonian, and Carboniferous. Unluckily, numerous fossils brought home by Sir John Richardson in 1826 have been mislaid.

¶ Appendix to Sutherland's Journal of Capt. Penny's Voyage, 1850-51, (London, 1852) vol. ii. with plates. See also Quart. Journ. Geol. Soc. vol. ix. p. 312, 1853.

N. GENERAL SECTION ACROSS THE OLDER ROCKS OF LOWER CANADA NEAR THE MOUTH OF THE ST. LAWRENCE. S.

L. Laurentian. *a.* Lower Silurian (consisting, in Canada, of Potsdam Sandstone, Lower Calciferous Sand-rock, Trenton Limestone, Utica Slate, and the Hudson-river Group). *b.* Upper Silurian. *c.* Devonian. *d*[1] Lower Carboniferous rocks. *t.* Trap-dykes.

This diagram, exhibiting the general succession of the Lower Palæozoic rocks, was drawn, thirteen years ago, by Sir William Logan, to show how, in the eastern portion of Canada, the ancient crystalline rocks, since termed Laurentian (*L*), are unconformably overlapped (the Huronian or Cambrian rocks being omitted in this tract) by Lower Silurian rocks, *a*, consisting of Potsdam Sandstone, Lower Calciferous Sand-rock, Trenton Limestone, Utica Slates, and the Hudson-river Group. The superior rocks (Upper Silurian, Devonian, and Lower Carboniferous, *b, c, d*) succeed. The strata have been much contorted, as in the eastern region of the United States. (See also Logan, Quart. Journ. Geol. Soc. vol. viii. pp. 203, 206; and the Reports of the Canadian Survey for 1863 and 1866.)

von Buch.; with Upper Silurian forms of Orthoceras, Murchisonia, Strophomena, Orthis, Rhynchonella, &c., besides Encrinites, and very numerous Corals, including the Chain-coral, Favosites Gotlandicus, F. cristatus or polymorphus, and several other species characteristic of this division of the Silurian system, and, as might be expected, of American rather than European types.

The same inference has been drawn by the geologists who have surveyed the rocks, and the naturalists who have examined the fossils, of the northern edge of the great gneissic region of the Laurentide Mountains. Their conclusion is, that, whilst on the south side a succession is seen from the crystalline strata into a copious and diversified Lower Silurian, as above explained, the northern side of the Hudson's Bay territory is chiefly occupied by Upper Silurian limestones *. This inference is founded on the occurrence, at the base of the whole fossiliferous series in that district, of a profusion of Corals, several of which are characteristic of the Niagara and Onondaga Limestones (Wenlock or Dudley), together with the Trilobite Encrinurus punctatus, the Shells Atrypa reticularis and Pentamerus oblongus, with several other Mollusca (Ormoceras &c.) indicative of the lower portion of the Upper Silurian group. Now, as in all the vast extent of land that has been surveyed in the Polar circle, no trace of the Lower Silurian formations has yet occurred †, the inference seems justifiable that during that period the Polar land, or all the region north of the Laurentide dome, was raised above the water, and was subsequently depressed to receive successively the Upper Silurian, Devonian, Carboniferous, and even some Secondary deposits ‡.

* Sir W. Logan has found that these limestones at the head of Lake Temiscamang include enormous blocks of the sandstone on which they rest; so that, in all probability, they are littoral deposits, and Pentamerus was not a deep-sea shell.

† The two highly enterprising Arctic expeditions undertaken through the zeal and munificence of American gentlemen, the first under Dr. Kane, the second under Dr. Hayes, which reached the most northern lands ever explored, have quite confirmed the view which is taken in the text. In the first of these expeditions, some headlands ranging far away to the north-eastern side of Kennedy Channel (beyond Smith Sound) were sighted to the north of Grinnell Land. Dr. Hayes has since penetrated to a bay in lat. 81° 35′, which he has most properly named after Lady Franklin. From the adjacent cliffs he has collected numerous fossils which, having been examined by Professor Meek, prove to be all Upper-Silurian forms. Dr. Hayes has named one of the northernmost of the larger promontories Mount Murchison; and, as the author of the 'Silurian System,' I am naturally gratified by this distinction. (See his work, 'The Open Polar Sea,' London, 1867, pp. 72, 340 *et seq.*)

‡ Permian limestone has been found as a drifted block at Spitzbergen, but has not yet been observed in the Arctic regions of North America. Certain Secondary limestones, charged with Ammonites and bones of Ichthyosauri, occur in the most northern latitudes explored. See Belcher's 'Last of the Arctic Voyages,' vol. ii. pl. 35; M'Clintock, Journal of the Royal

Looking, indeed, to the vast and little-accessible Arctic region, the geologist has good reason to be thankful for knowledge which has enabled him to classify the older sedimentary rocks of icy regions never trodden by civilized man before the present century.

In terminating this brief outline of the succession of the older fossiliferous rocks of America, let me remind the reader of the vast extent to which this continent is composed of Silurian, Devonian, and Carboniferous formations. In the Western hemisphere, as in Europe, the first signs of life are met with at the same low horizon in the crust of the earth; and similar great groups are clearly distinguishable. We also observe that Fishes, which, so far as clearly known, were called into existence only towards the close of the Silurian period *, and were of such peculiar forms in the Devonian epoch, become conspicuous in the Carboniferous deposits of America, and exhibit many new types, including the remarkable large Sauroid Fishes of Agassiz. Again, with a considerable amount of land vegetation in the Devonian, the Carboniferous rocks of America are characterized by the same abundant flora, and even by many species of the same shelly remains, as in Europe, together with sauroid animals. The only essential difference which, when the first edition of this work was published, was supposed to exist between the older rocks of the two hemispheres was, that America offered no indication of the upward termination of Palæozoic life, which in Europe is marked by the Permian deposits. That distinction even has now been removed by the discovery of strata containing many true Permian species in the north-eastern part of Texas; and the same formation is now known to occur also along the eastern edge of the Rocky Mountains †,—thus teaching us that

Dublin Society, Feb. 1857, p. 26; and Report Brit. Assoc. 1855, Trans. Sect. p. 211.

* Reasons were adduced, in the first edition, to prove that the forms supposed to belong to Fishes in the Niagara-limestone and Clinton Groups were probably parts of Crustaceans or of Annelides. The earliest Fishes yet known are from the Lower Ludlow rock.

† The fossils which have brought out this coincidence between the youngest Palæozoic rocks of the New and Old World, were discovered by Major F. Hawn and Dr. Cooper, and being sent by them to Mr. Meek of New York, that gentleman and Dr. Hayden described some of them as belonging to Monotis, Myalina, Bakevellia, Leda (Nucula), Pleurophorus, Panopæa, Nautilus, &c. See Trans. Albany Institute, March 1858. These authors had no doubt that the shells were of the Permian age. Professor Swallow of Missouri, to whom another collection had been sent by Major Hawn, arrived at the same conclusion, and enumerated several species identical with European forms, also many Corals. As these Permian fossils have already been procured from spots 100 miles distant from each other, and have been even traced to the northern border of Missouri, the strata in each case overlying the eroded surfaces of the Carboniferous rocks, I agree with the suggestion of Mr. Meek and Dr. Hayden, that the formation will be found to have a considerable geographical range in the far West.

M. Jules Marcou (who passed some months in the elevated region of the Rocky Mountains of Mexico) has discovered an Upper Carboniferous zone covered by a magnesian limestone, and followed by Triassic, Jurassic, Cretaceous, and Tertiary rocks. This view of the order of succession was communicated in 1853 to the Geological Society of France; and, recurring to it in other works, and in his general map, published in succeeding years, M. Marcou afterwards brought together all his observations in one volume. ('Geology of North America; with two Reports on the Provinces of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally made for the United States Government.' April 1858, Zurich. See also Bibl. Univ. de Genève, Juin 1858.) That the magnesian limestone above the Coal, of which that author has spoken, is truly of Permian age, has recently been thoroughly ascertained through Professor Geinitz's examination of its fossils brought from the cliffs of Nebraska City by M. Marcou. In one central band of these rocks, 63 fossils were found. Of these, 22 species prove to be known in the Permian rocks of Europe, 21 are new species, and 20 are common to the Permian and Carboniferous deposits. (See Marcou, Bull. Soc. Géol. de France, vol. xxi. p. 132, and Geinitz, Jahrbuch, 1867, pp. 1-9.) This collocation of fossils proves indisputably that the Permian formation in America is, as in Europe, truly Palæozoic; being linked on to the Carboniferous system just as Devonian rocks pass upwards into the Carboniferous and downwards into the Silurian system. We are thus well assured that the numerical term *Dyas*, which Geinitz and Marcou would substitute for the generally re-

all the seas of Palæozoic times, even the very last of them, had a very great extension, and were inhabited by similar groups of animals over enormously wide areas.

In concluding the Twelfth Chapter I stated that much important information respecting the geological position of the great oil-bearing formations of North America would be communicated in the sequel; and, thanks to Dr. Sterry Hunt, I now offer a view of these deposits and their origin which will, I doubt not, be as new to many of my readers as it was to myself when I first perused that excellent work 'The Geology of Canada.'

Petroleum in North America.—Petroleum occurs at several horizons in the great Palæozoic basin of North America. The lowest source is in the Lower Silurian limestones of Trenton, which are more or less oleiferous from Quebec to the Manitoulin Islands in Lake Huron, and thence to Chicago, and southwards as far as Kentucky and Tennessee. The great overlying mass of sandstones, shales, and dolomites which make up the remainder of the Silurian system is destitute of petroleum; but the Corniferous or Lower Devonian Limestone is, like that of Trenton, oil-bearing, and furnishes the petroleum of the south-western peninsula of Canada, and of some parts of Kentucky, in both of which regions the wells are often sunk directly into this limestone. In the intermediate region it is generally overlain conformably by higher Devonian and Carboniferous rocks, in both of which, however, important oil-wells are found. Those of Western Pennsylvania are sunk in the shales and sand-rocks of the Upper Devonian.

The observations of that accomplished mineralogist and geologist Dr. Sterry Hunt, as recorded in the 'Geology of Canada,' pages 522–525, and in Silliman's 'American Journal' for March 1863, show that the oil in the two limestone formations above mentioned could not have been introduced by a subsequent process, but must have been indigenous to certain beds of the rock. When these limestones, or their overlying strata, are more or less disturbed from their horizontal position, the petroleum escaping from these beds finds its way to the surface, or else accumulates in the fissures of the anticlinals where these are stopped or closed by overlying impermeable clayey strata. In some cases the Quaternary gravels, covered by clays, which overlie these Palæozoic rocks, serve as reservoirs for the oil, and constitute what are called surface-wells. It is considered probable by Dr. Hunt that the oil-fissures in the Devonian sandstones of Pennsylvania may have been filled from the underlying limestone formation, inasmuch as there appears to be as yet no evidence that oil is indigenous in these Upper Devonian strata. The great conglomerate at the base of the coal in Kentucky appears to hold, according to Lesley, indigenous petroleum. Apart from this, however, it would seem that this substance belongs to the pure or non-magnesian limestone formations of the Palæozoic series. The Lower Carboniferous Limestone of Kentucky is, according to Lesley, oil-bearing; and it is

ceived geographical name 'Permian,' is wholly inapplicable in America, where the formation (at Nebraska City) is a *Monas*, or one calcareous mass. In truth, the group varies from a single to a quadripartite diveision, according to the country examined, and thus the simple geographical term 'Permian' is suited to embrace all such variations, whilst that of *Dyas*, intended by M. Marcou to indicate some relation to the *Trias*, is, by virtue of its fauna, entirely separated from that Secondary group.

Let me add that it will be a subject of great interest to me, should the Permian zone be found to range northwards through the United States into the British territories. For certain small Producti, and other fossils in a magnesian limestone brought home by Sir John Richardson in his early travels with Franklin, and which have been mislaid, were, I believe, Permian; and in this case, a zone of that age may be said to extend at intervals from Mexico even into the Arctic regions watered by the great Mackenzie River.

worthy of remark that in Gaspé, in the eastern subdivision of the great Palæozoic basin, where the whole of the Devonian consists of sandstones, the pure limestones which there represent the Upper Silurian are oleiferous.

The observations of Professors Andrews and Evans of Ohio, as well as those of Dr. Sterry Hunt, have shown that the available supplies of oil are met with along the crowns of gentle undulations, where fissures, often nearly vertical, contain the accumulation of ages, frequently accompanied by quantities of gas, whose elasticity raises the oil to the surface and gives rise to the flowing or spouting wells. A certain amount of undulation is thus required to facilitate the accumulation of the oil (which from its levity ascends to the higher parts of the strata), and also to give rise to the requisite fissures or reservoirs. Too great a disturbance of the rocks, however, allows the oil to run to waste. Its alteration by evaporation and by oxidation in fissures gives rise to solid matters, which vary from a kind of asphalt to more or less insoluble coal-like bodies like what have been named Albertite and Grahamite. These matters fill great veins in the Carboniferous rocks of West Virginia, and are also described by Dr. Hunt as occurring in Lower Silurian rocks in Canada, where they are found lining or filling fissures, and sometimes assuming mammillary or stalactitic forms. Such materials are even met with in veins in the old Laurentian limestones, converted, however, into something like anthracite. According to Dr. S. Hunt, it is to the comparatively undisturbed character of the Palæozoic rocks of North America that the preservation in them of such large quantities of petroleum is due; and he supposes that this substance was once not less widely distributed in the Palæozoic rocks of other regions, where, however, the conditions for its preservation have been less favourable than in North America*. In those parts of North America where the oleiferous strata are nearly or quite horizontal, the borings seem to have yielded little or no petroleum, for the obvious reason that the inclination of the strata which would enable the oil to ascend through the joints of the strata to higher levels is there wanting. This relation of the oil to the lines of uplift is remarkably seen, says Dr. Hunt, along the great Cincinnati anticlinal, a gentle undulation which stretches from the head of Lake Ontario in a south-western direction for about 500 miles to the Cumberland Valley in Kentucky, dividing the great carboniferous areas of North America. This anticlinal brings up in the Cumberland region the Lower Silurian strata rich in petroleum, but near its north-eastern extremity is covered by the Middle and Lower Devonian strata, in which are sunk the oil-wells of Western Canada. The further relation of these to the numerous subordinate undulations, parallel to the great anticlinal, is shown in detail in the Report on the Geology of Canada for 1866.

Petroleum is generally associated with saline waters, and, according to Dr. Hunt, for the very obvious reason that the comparatively undisturbed marine strata in which it occurs are everywhere permeated by the water of the primeval oceans, which naturally finds its way to the surface along the same lines as the petroleum. In addition to these ancient sea-waters, true saliferous formations exist in many regions, and yield pure brines from the solution of rock-salt. These formations, however, belong to different and distinct formations from those bearing petroleum. Thus, in Western Canada, after penetrating the Lower-Devonian oil-horizon, the gypsiferous and salt-bearing Onondaga formation of the Upper Silurian is encountered; and in the adjacent parts of the United

* It is worthy of remark that the great supplies of petroleum in most other parts of the world are derived from Mesozoic and Cænozoic formations.

States two other salt-formations are met with, the one above and the other below the Carboniferous Limestone. These salt-formations, derived probably from the drying up of sea-basins or salt lakes, are naturally limited in their area when compared with the widespread oil-bearing formations which were deposited in the open sea.

With regard to the origin of petroleum, Dr. Hunt adopts the conclusion deduced by Mr. Wall from his researches in Trinidad*, that its source is to be found in a peculiar transformation of organic matters, either animal or vegetable, under conditions unlike those which give rise to coal. This process, according to Dr. Hunt, has probably been effected in comparatively deep waters, where oxygen was excluded, and the carbon, retaining its maximum of hydrogen, was converted into liquid or solid bitumen, which is thus in these cases the only representative of the organic tissues which in different conditions would have given rise to coaly or lignitic matters. The preservation of these tissues in such forms is thus incompatible with the production of petroleum; and there exists no connexion whatever between this substance and the beds of flaming coal and schists (pyroschists) which, Dr. Hunt adds, are incorrectly termed bituminous, not because they contain bitumen, but because they may be made to yield volatile hydrocarbons by destructive distillation.

* See Report on the Geology of Trinidad, Mem. Geol. Survey, 1860; also Quart. Journ. Geol. Soc. vol. xvi. p. 467.

BLE OF THE ORDER OF SUPERPOSITION OF THE LAURENTIAN, HURONIAN, SILURIAN, AND DEVONIAN STRATA OF CANADA AND THE STATE OF NEW YORK, ETC., COMPARED WITH THEIR BRITISH EQUIVALENTS: WITH LISTS OF SOME CHARACTERISTIC FOSSILS.

ish ral ai- nts.	UPPER.	Old Red Sandstone of the Catskill Mountains			Euomphalus depressus. Holoptychius nobilissimus, and a few Plants.
DEVONIAN.	UPPER.	Chemung Group			Sigillaria, Ferns, Lepidodendron; Orthis, Atrypa, Strophomena, Leptæna, Productus, numerous Spirifers; Avicula pectiniformis, and other Aviculæ, like Aviculopectens.
DEVONIAN.	UPPER.	Portage Group			Fossils few. Orthis, Spirifer; Bellerophon, Goniatites, Orthoceras; Cyathocrinus.
DEVONIAN.	MIDDLE.	Upper Helderberg Group.	Hamilton Group.	Genesee Slate. Moscow Shale. Marcellus Shale.	Chonetes, Orthis, numerous Producti; Spirifer, about 17 species; Cyrtia, 20 species; Atrypa reticularis. Rhynchonellæ. *Upper limit of Pentamerus.* Many Lamellibranchiata—Orthonota, Grammysia, Avicula or Aviculopecten, Mytilus Chemungensis, &c. Euomphalus, Pleurotomaria, Bellerophon (like B. expansus). Many species of Goniatites, the largest a foot across. Many Orthoceratites. Encrinites; Palæaster. Trilobites of the genera Phacops, Proetus, Dalmanites, and Homalonotus.
DEVONIAN.	MIDDLE.	Upper Helderberg Group.	Corniferous Limestone		Encrinital stems, the largest 1⅜ inch in diameter. Atrypa reticularis; Pentamerus arcuatus (characteristic). Numerous Strophomenæ; Merista; Chonetes; Spirifer 15 species, chiefly short-hinged; Meganteris, Aviculopecten, and other Aviculoid Shells. Various Gasteropoda. Cephalopoda, viz. Lituites, Trochoceras, Phragmoceras, Cyrtoceras, Orthoceras (some with annular projecting lamellæ). Goniatites. Calymene Blumenbachii, var. major?; Phacops, Proetus, Dalmanites. 'Old Red' Fishes. Resembles the Hamilton group.
DEVONIAN.	LOWER.	....	Schoharie Grit		Fishes as above. Pentamerus arcuatus, Atrypa impressa (like A. reticularis).
DEVONIAN.	LOWER.		Cauda-galli Grit..................		Sea-weeds.
DEVONIAN.	LOWER.		Oriskany Sandstone		Orthis unguiformis &c., Strophodonta, Strophomena depressa?; many large Spirifers; Rhynchonellæ, large; Meganteris, 2 species; many Gasteropoda—Acroculiæ &c. Assemblage peculiarly characteristic of this division.
ER SILURIAN (Murchison).	UPPER SILURIAN.	Lower Helderberg Group. Ludlow beds.	Upper Pentamerus Limestone ...	Pentamerus pseudo-galeatus.	Eleven species of Orthis, some identical with or representative of Niagara species; Lingula, 3 species; Strophomena depressa and S. euglypha, or punctulifera of Hall; Spirifer perlamellosus in immense quantity, S. cyclopterus, S. concinnus, and others; Meganteris elongata; Meristæ numerous; Rhynchonella Wilsoni, varieties; Atrypa reticularis; numerous Aviculæ, like Aviculopectens. At this period the Palæozoic Gasteropoda of America assumed their greatest development. Trilobites—Phacops, Dalmanites, Lichas, Proetus, Acidaspis, Homalonotus, &c.
			Encrinital Limestone.		
			Delthyris Shaly Limestone	Pentamerus Verneuilii, &c.	
			Lower Pentamerus Limestone ...	Pentamerus galeatus, &c.	
			Stromatopora Limestone.		
			Tentaculite Limestone	Tentaculites ornatus, &c.	
		Onondago-Salt Group			Atrypa, Delthyris. Pentamerus occidentalis, like P. Knightii, but smaller; Megalomus Canadensis; Merista; Murchisonia, Pleurotomaria, &c. (Eurypterus remipes in the upper beds.)
		Niagara Group (Wenlock).	Niagara Limestone...............		Numerous Corals, chiefly in the limestone; Polyzoa in the shale. Lowest zone, Cystideans. Many of the fossils, viz. Orthis, Spirifer, Leptæna, and Atrypa, are of the same species as, and others representative of, those in England.
			Niagara Shale.....................		
					Graptolithus Clintonensis, G. (Retiolites) venosus, Tentaculites, and Cornulites; *Pentamerus ovalis* in upper part, and *P. oblongus* in lower beds; Lingula oblonga, Chonetes cornuta, Leptæna depressa, L. sericea, L. transversalis, and others not European; Spi- ... iformis, Posidonia alata, Modio-

LOWER SILURIAN (Murchison).	MIDDLE SILURIAN.	Lower Llandovery Rocks.	Medina Sandstone	migenia and M. orthonota; Pleurotomaria pervetusta; Fucoids, Cruziana ?, &c. In Anticosti (Billings), Stromatopora concentrica, Leptæna alternata, L. subplana, Atrypa congesta, A. reticularis, *Pentamerus Barrandi*, Calymene Blumenbachii.
			Oneida Conglomerate	Corals: Chætetes lycoperdon, Catenipora escharoides, &c. Leptæna sericea, L. subplana, and L. transversalis, Strophomena alternata and S. depressa, Orthis lynx and O. testudinaria, Atrypa naviformis, *Pentamerus reversus*; Bellerophon bilobatus; Calymene Blumenbachii.
	LOWER SILURIAN.	Caradoc Beds.	Hudson-river Beds	Fossils in great part the same as in Trenton Limestone. Tentaculites; Orthis testudinaria, O. subjugata, O. sinuata, O. plicatella, &c.; Strophomena alternata, S. planumbona, Leptæna sericea; Orbicula crassa; Rhynchonella increbescens, Hall; Bellerophon bilobatus; Ambonychia radiata, very characteristic, as in Britain; Modiolopsis modiolaris, common; Avicula demissa; Orthonota parallela. Encrinites: Glyptocrinus basalis, &c.; Palæaster; Calymene senaria. Triarthrus Beckii, Trinucleus concentricus, Isotelus megistos, I. gigas. (Clearly equivalent to the Caradoc or Bala beds.)
			Utica Slate	Black bituminous graptolitic shale. The Graptolites in this and the Hudson-river beds, as given by Hall, are G. pristis, G. mucronatus, G. ramosus, G. sagittarius, G. tenuis, G. sextans, ands everal other species. Lingula; Orbicula, Orthis testudinaria; Leptæna sericea; Trilobites, chiefly the same as in the division above, Asaphus latimarginatus, &c.
			Trenton and Bird's-eye Limestones	Very fossiliferous. Especially rich in Crinoids. Cystideans; Starfish (Palæaster matutinus); Chætetes Petropolitanus, C. lycoperdon, C. columnaris; Retepora; Streptelasma; Lingula quadrata; Leptæna sericea; Strophomena tenuistriata, S. alternata, abundant; many species of Atrypa, A. increbrescens &c.; many Acephala, Avicula Trentonensis, Tellinomya, &c.; species of Pleurotomaria. Holopea, and Murchisonia; Bellerophon bilobatus; Asaphus Barrandi, Isotelus gigas, Ceraurus pleurexanthemus and C. vigilans; many Cephalopoda of the genera Oncoceras, Lituites, Orthoceras, Cyrtoceras, Trocholites, Endoceras; Illænus crassicauda, Phacops callicephalus, Triarthrus Beckii, Calymene senaria, 3 sp. of Acidaspis, Trinucleus concentricus, Olenus, &c.
		Llandeilo Beds.	Chazy, Sillery, Lauzon and Lévis Limestones } Quebec Group	Fossils, as a whole, much the same as those of the Trenton Limestone. Ormoceras tenuifilum, and Gonioceras unknown in England.
			Upper Calciferous Sand-rock	Several species of Murchisonia, M. angustata, &c., and of Pleurotomaria; Orthocerata.
	'Primordial.'	Tremadoc Slates.	Lower Calciferous Sand-rock	Polyzoa and Corals of the genera Retepora, Ptilodictya (Stictopora), Petraia (Steptelasma), and Chætetes; with Encrinites; Leptæna, Orthis, Atrypa; Maclurea magna, Scalites, Raphistoma, Murchisonia, &c.; Illænus, Asaphus ?; Isotelus gigas ?, I. canalis.
			Upper Potsdam Sandstone	
		Lingula-flags.	Lower Potsdam Sandstone	Ophileta compacta, O. ? (Maclurea) sordida, Maclurea matutina, Turbo, and Pleurotomaria ?; Orthoceras, 2 sp.; Lingula prima and L. antiqua; Scolithus linearis; Cruziana; and Sea-weeds.
			St. John's Group	
CAMBRIAN.			HURONIAN of America.	No fossils have as yet been found in this zone in America.
LAURENTIAN of Scotland.			LAURENTIAN of America.	Eozoon Canadense.

Note.—This Table, as printed in the last edition, was prepared by Professor Ramsay after a visit to North America. It has now been improved by the recent adjustments of the classification by Sir W. Logan, as mentioned in the preceding pages,—particularly as regards the Lower Silurian and the introduction of the Quebec Group.

CHAPTER XIX.

ON THE ORIGINAL INTRODUCTION OF GOLD INTO THE EARTH'S CRUST AND ITS SUBSEQUENT DISTRIBUTION IN DÉBRIS OVER VARIOUS PARTS OF THE SURFACE.

CONSIDERING the great quantity of Gold which has of late years been found in California and Australia, it may be expected that an author who has borne a part in the discussions upon this subject* should devote some pages to so engrossing a topic,—the more so as my chief article of belief has now proved to be true, viz. that the rocks which are the most auriferous belong to the Palæozoic epochs, and especially to the Lower-Silurian age. At the same time I have to modify to some extent that aphorism; for it will be shown that there are examples of auriferous igneous rocks and veinstones having been protruded into strata of Secondary age, the latter having become to some extent auriferous,—a fact unknown to me when the last edition of this work was published. The views now put forth will chiefly relate to the geological and mineralogical conditions under which gold has occurred. As a clear understanding of this point may tend, in some measure, to allay the fears of those who think that the metal may be discovered over regions vastly more enormous than the tracts to which it is restricted, certain geological and statistical data and arguments that I have advanced in greater detail in other works are here brought together.

Let us first reflect upon the general fact that, whilst all the stratified formations are composed either of crystalline and Palæozoic rocks or of Secondary and Tertiary deposits, gold has never been found in any appreciable quantity in either of the two last-mentioned classes of strata where they are in their natural state, *i.e.* where they have not been penetrated by igneous rocks or metamorphosed and impregnated with mineral veins. The vast areas, therefore, which are covered by all such younger unaltered formations are excluded from the general auriferous area; and every one who lives in tracts the subsoil of which consists of such unaltered rocks, may at once be assured that he can never find gold in them.

Having laid down this generalization, which affirms that by far the largest countries contain little or no gold, we proceed to consider the

* See 'Russia-in-Europe and the Ural Mountains,' p. 437 *et seq.*; Trans. R. Geogr. Soc., President's Discourses, vol. xiv. 1844-1845,—in the first of which the Australian rocks were compared with those of the Ural. Trans. Royal Geological Society, Cornwall, 1846, p. 324 *et seq.*, in which Cornish tin-miners were incited to emigrate and work for gold in Australia. Report of the British Association for the Advancement of Science, 1849 (Trans. of Sections, p. 60). Proceedings of the Royal Institution, March 1850. Quarterly Review, 1850, vol. lxxxvii., Article 'Siberia and California,' p. 39. Quart. Journ. Geol. Soc. Lond. vol. viii. p. 134. And, lastly, 'Further Papers on the Recent Discovery of Gold in Australia,' presented to Parliament Aug. 16, 1853, p. 43, including my correspondence, in 1848, with Her Majesty's Secretary for the Colonies, on the then known existence of gold in Australia, and tendering my advice as to the manner of opening out useful gold-works in the Colony.

nature of the gold-bearing rocks themselves, as well as the limits of the auriferous Drift, whether gravel or other superficial materials.

Appealing to the structure of the different countries which at former periods have afforded, or still afford, any notable amount of gold, we find in all a general agreement. Whether, referring to ancient history, we cast our eyes to the countries watered by the Pactolus of Ovid, to the Phrygia and Thrace of the Greeks, to the Alps * and golden Tagus of the Romans, to the Bohemia of the Middle Ages, to tracts in Britain which were worked in old times, and have either been long abandoned or are now scarcely at all productive, or to those chains in America and Australia which, previously unsearched, have in our times proved so rich,—we invariably find the same constants in nature. In all these lands gold has been imparted abundantly to those ancient rocks only whose order and succession we have traced in the foregoing Chapters, and, as I believe, by the agency of the associated eruptive rocks. The original position of the metal most usually is in quartzose veinstones traversing altered Palæozoic slates (often Lower Silurian †), frequently near their junction with eruptive rocks, it being also found diffused through the body of rocks of igneous origin. The Palæozoic accumulations which followed from the Lower Silurian up to the Carboniferous inclusive, however (and chiefly the oldest of them), have been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure by igneous agency, or have been penetrated by quartz-veins, are the *chief* sources whence gold has been or is derived.

However we may account for them, the facts are those which I have for many years exposed—viz. that besides igneous rocks, whether granites or diorites, which have carried up gold in their matrix, certain geological zones only in the crust of the globe have been rendered richly auriferous.

Gold in Britain.—The British auriferous examples, comparatively small in produce as they have been, will be first briefly alluded to, because the reader can at once refer, in the coloured map of this work, to two districts of Wales wherein gold has been found, and in one of which it is now in the course of extraction. (See the golden-spotted patches in North and South Wales.)

In the Lower Silurian rocks, about ten miles west of Llandovery, at a spot called Gogofau, near Llan-pümp-saint, large white quartzose veinstones, traversing slaty masses, were cut into by the Romans, who excavated lofty galleries, which are still open. That enterprising people evidently derived gold from portions of these veinstones. Many gold ornaments have, in fact, been found at the adjacent Roman Station of Cynfil-Cayo, with traces of aqueducts, built probably to convey water to wash the gold. Even the grindstones ‡ and troughs used in abrading the hard matrix are yet to be seen.

* In truth, as above expressed, every old country of Europe where the rocks were once auriferous has long ceased to yield any valuable amount of gold. In reference to the Alps, I am indebted to my lamented friend the late Mr. J. W. Cowell for pointing out to me the following passage in Strabo (Book iv. ch. 6. sect. 12), by which it appears that even Imperial Rome was at one time inundated with a glut of gold from her northern mountains:—"Polybius says that in his time the gold mines were so rich about [north of?] Aquileia, but especially in the country of the *Taurisci Norici*, that if you dug but two feet below the surface you found gold, and that the diggings (generally) were not deeper than 15 feet; that in some instances the gold was found pure, in lumps of the size of a bean or a lupin, and which lost only one-eighth in smelting; in others it required more smelting, but was very profitable. Italians aiding the Barbarians in the working for two months, gold became forthwith one-third cheaper over the whole of Italy; and the Taurisci discovering this, drove the associate Italians away and monopolized it themselves. At present all gold-mines belong to the Romans."

† Gold has recently been detected in a veinstone even in the Laurentian rocks of North America.

‡ See 'Silurian System,' p. 368. At the time of the publication of that work (1839) I had not visited the Ural Mountains, and was little acquainted with the nature of gold-bearing rocks and the methods employed for the extraction of the metal, or I should at once have recognized as certain what I only ventured to suggest—that

In North Wales, where similar but older strata have been more crystallized and infinitely more penetrated by igneous rocks, gold was not only obtained in ancient times, but is still found to some extent. In Merionethshire some of the older slaty rocks were twenty years ago announced, by Mr. A. Dean, to be auriferous*. The district then referred to, which lies to the north of Dolgelly, and to the north and west of the small river Mowddach, has since been resurveyed by Professor Ramsay, who has described the precise geological relations and mineral character of several metalliferous lodes, which, poor in lead and copper, are slightly charged with gold †. The lodes are subordinate to the Lingula-flags or Lowest Silurian, as well as to the adjacent Cambrian rocks; and these being traversed by trap-dykes (including magnetic greenstone), as well as bounded by a large mass of eruptive rock, are much altered, often into a talcose and chloritic schist, and are traversed by quartz-veins containing much iron-pyrites. The principal localities where the gold had then been observed are Cwm-eisen-isaf and Dol-y-frwynog. One of the veinstones at the latter place consists of white saccharoid quartz, in some of which small flakes of gold are distinctly visible to the naked eye. Professor Ansted, who has examined the same gold-veins *in situ*, reported to me that, at Dol-y-frwynog, the gold is disseminated both in grains and in laminæ enclosed in irregular veins, parallel to the Lower Silurian schists, and contiguous to a poor lode of copper-ore, the whole lying near a greenstone within the slaty rocks. The auriferous bands, he says, are made up of numerous threads of quartz and sulphate of barytes, which, besides the grains and flakes of gold, contain crystals of galena and copper-pyrites.

Mr. Warington Smyth, who had previously examined this mine, has devoted much attention to other auriferous veins in this district, and particularly to that called St. David's Lode, which intersects the Lingula-flags near the old copper-mines of Clogau. The lode, which is very definite, although variable in character, has yielded, from workings of moderate extent, probably not less than £70,000' worth of gold ‡.

At a few places in Cornwall § and Devonshire, gold has long been known to exist in small quantities, both in the matrix of mineral lodes and occasionally in accumulations of rolled materials. The Poltimore mine, near North Molton, Devon (where certain schists of Upper Devonian ? age are mineralized, and were formerly worked for copper), was said in 1853 to promise a rich auriferous result; but since the issue of the first edition of this work the speculation has been abandoned, it having been proved (as I suggested to the noble proprietor would be the case) that no sufficient body of gold-bearing matrix would be found to repay the cost of the works. The coarse ancient alluvium or gravel of Cornwall, whence the tin-ore has been extracted, as well as some other portions of Drift in that county, have indeed long afforded small quantities of gold; but, although the largest fragments have occasionally been of the size of a pigeon's

the rock might formerly have been quarried for the gold it contained. Suspecting that some traces of gold might be detected in the pyritous refuse of the quartz-rock, I submitted a little of it to the late eminent chemist, Dr. Turner; but he could not detect a trace of the precious metal. Subsequently, however, Mr. Warington Smyth and Dr. Percy detected a small quantity of gold diffused in these quartz veinstones. See Memoirs of the Geological Survey, vol. i. p. 480; also an exposition of the relations of gold, in the 'Lectures on Gold' by E. Forbes, Jukes, Playfair, Percy, Warington Smyth, and Hunt.

* Report Brit. Assoc. Adv. of Science, 1844, Trans. of Sect. p. 56.

† Quart. Journ. Geol. Soc. Lond. vol. x. p. 242. See also Mr. Readwin's notes on the gold-produce of this district, read before the British Association in 1863 and 1865.

‡ The quantity of gold raised from this lode between April 1860 and May 1867, as officially accounted for to Her Majesty's Office of Woods and Forests, is 12,416 oz. Appearances are at the present moment very promising. See Appendix.

§ Mr. S. R. Pattison read before the Geological Society (February 1st, 1854) a notice on auriferous quartz-rock near Davidstow, North Cornwall, the chief gold-bearing mass of which is the *gossan* of a dyke in a metamorphosed rock of Upper-Devonian age, which, mantling round the granite of Rough Tor, is also associated with dykes of trap.

egg, none of these superficial accumulations have been considered worthy of continuous exploration.

In Scotland, whilst slender traces only of gold have been detected in the older crystalline rocks of the Northern Highlands*, albeit many of them are now known to be of Lower-Silurian age, the metal was formerly found in the slates of the South of Scotland (Lead Hills), which, like those alluded to in North and South Wales, are also of that age. These South-Scottish gold-mines, after having, in the reign of James the Fifth, afforded a small sum, were abandoned as soon as the cost of production exceeded the value of the ore extracted †. They occurred in a region where the strata have been much penetrated by porphyries and other igneous rocks.

In Ireland we read the same lesson. It is from the altered Lower Silurian schists of Wicklow, which clasp around the eruptive granite of Croghan-Kinshela, and are traversed by hornblendic greenstones, that gold was derived; and fragments of it, detached from the sides of that mountain and washed down by the rivulets, continue to be still picked up by the natives ‡.

Now, if any portion of these old slaty British rocks, or their associated eruptive masses, had been largely penetrated by gold, then most assuredly much more auriferous débris would have been recognized in the local adjacent gravel —just as it occurs in all really gold-bearing lands. But as no rich auriferous sand or gravel is known in any part of the British Isles, we may rest satisfied that in our own country, as in many others, the quantity of gold originally imparted to the Silurian or other rocks was small, and has, for profitable working, been exhausted, with the exception of the mines north of Dolgelly §.

Even in Bohemia, which produced so much gold in the Middle Ages, and where the Silurian strata are, as we have seen (Chap. XV.), penetrated by many igneous rocks (and in parts much metamorphosed), there are now no gold-works, though other ores (copper &c.) are profitably extracted; and, just as in the rocky and mountainous tracts of Britain, very few places only can be cited which have been auriferous. The Thüringerwald, and some chains of Central Germany, also anciently afforded a little gold in rare and widely separated localities ‖; but these regions, as well as the Peninsula and its 'golden Tagus,'

* Near Loch Erne Head, a metalliferous veinstone observed by the late Marquis of Breadalbane was found to be slightly impregnated with gold. The gold occurred in a gossan, contiguous to the junction of trap with crystalline limestone and schists (probably of Lower-Silurian age), and is associated with arsenical pyrites and lead-ore.

† See Harkness on the 'Lower Silurian Rocks of Scotland,' Quart. Journ. Geol.Soc.vol.viii.p.396.

‡ The Earl of Wicklow, whose property is in the vicinity of the mountain of Croghan-Kinshela, has collected several 'pepitas' of this Irish gold, the largest being about two inches long. They are free from quartz or other rocky matrix, and have been picked out of the débris or coarse gravel on that slope of the hill where a rivulet descends through the property of the Earl of Carysfort. No veinstone *in situ* has ever been detected (Mills and Weaver, Trans. Dublin Society, and Weaver, Trans. Geol. Soc. Lond. 2nd ser. vol. i.); and although poor persons have stealthily procured specimens during this century, the quantity has never been sufficient to lead to the belief that really productive diggings could be opened at the Royal Gold-mine of Croghan. Tinstone is said to have been found with the gold here, as in Cornwall and other places (Fitton, Trans. Geol. Soc. Lond., vol. i. p. 270): the phenomena are well described by Professor W. W. Smyth, Records of the School of Mines, vol. i. p. 3, with a map; see also Proc. Roy. Geol. Soc. Ireland, January 11, 1865.

§ The reader who has attended to this subject will observe that the chief argument I have employed in other writings (see note, p. 448) to satisfy the public mind that auriferous sites in the old countries of Europe would for the most part prove slightly profitable only, was that all such works had ceased in former times for want of remuneration. Let me, however, say that, whilst I believe the old gold-tracts of Europe have, on the whole, been exhausted of their wealth, there may still be found spots where a little profit is attainable. I would further guard any inferences I have drawn from our previous state of knowledge, by saying that my opinions were formed irrespective of the new inventions in mechanical science. Crushing-machines and the improved application of mercury may, indeed, liberate a notable quantity of ore from a matrix of apparently slight value, and thus set at nought the experience of ages. Not pretending to enter into this mercantile part of the question, I adhere, however, to the belief expressed throughout the text, that gold will mainly be found in the old rocks indicated, and will, on the whole, be worked to the greatest advantage, as during past ages, in the natural débris of those rocks.

‖ The sands of the River Rhine (which drains so vast a rocky region) are in one part slightly auriferous; but the cost of extraction of the gold has been too great to repay the speculators.

so auriferous in the classical era, have, I repeat, long since ceased to offer any notable quantity of the precious metal.

The Ural Mountains.—No country furnishes a clearer example than Russia of the dependence of gold on certain geological and mineral relations. Her European territories are, as has been stated, chiefly occupied by slightly solidified primeval deposits. Under these conditions, and with a total absence of any crystalline rocks, whether of intrusive or of sedimentary and metamorphic characters, not a particle of gold has been discovered in them, over an area larger than the rest of Europe; but where the same formations have been thrown up into inclined and broken positions in the Ural Chain, and have there been pierced by porphyry, greenstone, syenite, and granite, in association with huge masses of serpentine, the very same deposits that are so soft in European Russia have been hardened, crystallized, veined, and rendered highly metalliferous, some of the igneous masses being also auriferous.

As the rocks in this chain, which separates Europe from Asia, are now known to be similar in character to those of numerous other auriferous ridges in Siberia and the Altaï Mountains of Asiatic Russia, the present description may serve to explain the composition of those vastly larger eastern tracts. The study of this Uralian Chain enabled me to suggest, in the year 1844, by comparison of the rocks of the two countries, that Australia would also prove to be an auriferous region. The survey of the Ural Mountains in 1842 led me further to define, within certain limits, the period when the Silurian rocks were chiefly impregnated with gold, and also to affirm that gold, as a distinct metallic mass, is of younger date, in that region, than the associated ores of copper and iron *.

With a watershed for the most part not exceeding 2000 feet above the sea, their highest peaks rarely rising above 5000 to 6000 feet, the Ural Mountains, throughout a north and south range of 18 degrees of latitude, are composed of rocks more or less crystalline, chiefly metamorphosed representatives of the Silurian and Devonian, and occasionally of the Carboniferous age. The Lower Silurian strata are, indeed, to be recognized in a crystalline state only. They are for the most part talcose schists, quartzites, and limestones; whilst the Upper Silurian, Devonian, and Carboniferous, though often also considerably altered (the limestones being frequently converted into marble occasionally dolomitic), offer here and there traces of their characteristic fossils. The flexures and fractures of the stratified rocks (Devonian and Carboniferous), as they approach the western flank of the altered and metalliferous axis of the chain, have been represented in the view of the gorge of the Tchussovaya, p. 366.

The following sketch will convey some idea of the wild and central, highly mineralized masses which in the Northern Ural peer out here and there from amid forests of the gigantic Pinus Cembra. It was taken by myself from the summit of the Katchkanar †, a rugged pile of stratified and jointed augitic rock, highly charged with magnetic iron. Platinum, as well as gold, has been

* See 'Russia-in-Europe and the Ural Mountains,' vol. i. p. 472 *et seq.* Also Journal of the Royal Geographical Society, President's Discourses, 1844–45.

† The following sketch of the approach to this mountain (visited, I believe, by no other European travellers) through the forests, is given in the work 'Russia and the Ural Mountains,' vol. i. p. 392:—"A large chaotic assemblage of loose angular blocks now lay around us, from amid which rose the magnificent Pinus Cembra, towering above all its associates, the rocks being overgrown with pæonies, roses, and geraniums. Such stony features alone would have led us to suppose that we were at the foot of the object of our exploration, when, in a few minutes, the broken and jagged outline of the Katchkanar burst upon our sight under a fine bright sun and amid the merry song of birds. The dull, wet, and marshy woodlands were now exchanged for sunshine and rocks. .... Accustomed as we have been to the wildest features of the Highlands of Scotland and the Alps, we are unacquainted with any scene presenting a finer foreground of abruptly broken rocks; and never certainly had we looked over so grand and trackless a forest as that which lay around us, and from which some straggling distant peaks (those on the north only being still capped with snow) reared their solitary heads."

washed down from the edges of this mountain and carried into the adjacent gorges on the east, though the sources whence these metals have been drifted into the coarse alluvium have not been detected.

While the traveller who crosses the Ural in the partial depression followed by the highroad to Ekaterinburg will scarcely be aware that he has passed over any dominant ridge, the geologist who explores the mountains from the south along their line of bearing soon perceives that, to the north, their crests are marked by lofty and usually snowy summits, as in the annexed drawing. To the south, the central mass near Zlata-ust consists of altered sandstone and quartzites, forming sharp peaks, that separate Europe from Asia *.

VIEW FROM THE SUMMIT OF THE KATCHKANAR, NORTH URAL.
(From 'Russia-in-Europe,' vol. i. p. 392.)
The snowy mountains seen in the distance to the north, are the much loftier peaks of Konjakofski Kamen &c.

Few chains offer more contrasting outlines than are seen upon the European and the Asiatic flanks of the Ural. On the former the limestones and other stratified rocks are indeed contorted, fractured, and partially changed, as before represented (p. 366), whilst in the centre, as on the eastern slopes, the masses consist everywhere either of highly altered and crystalline Silurian strata, or of the eruptive rocks which pierce them. There only, and particularly where the schists are cut by dykes of igneous rocks or traversed by veinstones of quartz, has gold been imparted in any quantity to the slaty, talcose, and chloritic strata. Though some efforts were made by the earlier Russian miners to extract gold from the solid matrix by underground works, such a process was not continued, it having been found infinitely more profitable to extract the ore from the broken accumulations of ancient drift deposited on the slopes of the hills or lodged in the higher valleys wherein small watercourses meander.

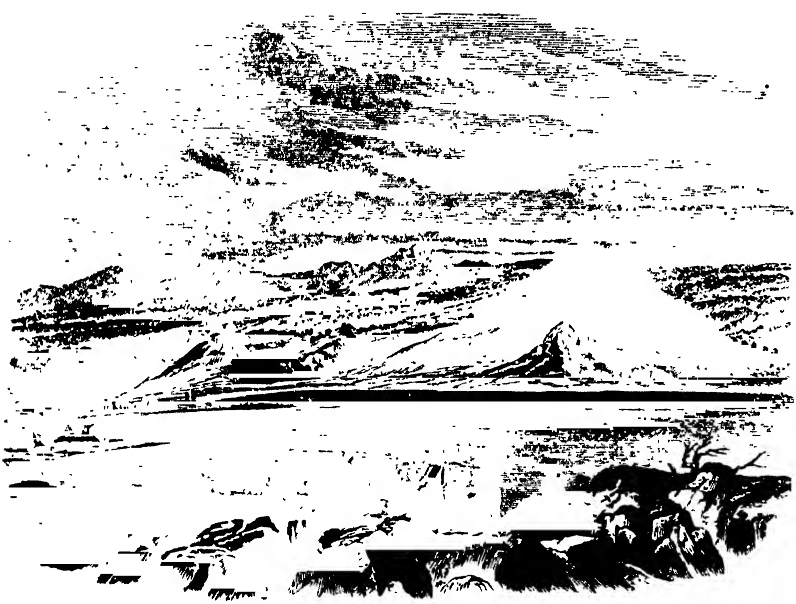
The only work at which subterranean mining in the solid rock is still prac-

* See the frontispiece of 'Russia and the Ural Mountains.'

tised, and with very small profit, is at Berezovsk near Ekaterinburg. There the shaft traverses a mass called 'beresite,' a decomposing granite with veins of quartz, in which gold is disseminated. In this case it is apparent that the gold-bearing rock is a true granite. The syenite of the Peschanka mines, near Bogoslofsk, is likewise impregnated with particles of gold, and the surface-degradation of that rock affords profitable washings. Much further to the east, in Siberia, Colonel Hoffmann long ago indicated a tract where even the schistose stratified rocks are equally permeated by the small diffused particles of the metal, imperceptible to the naked eye.

The prevailing practice, however, has hitherto been, to grind out the Uralian gold (by water-mills) from the broken or drifted materials only, and collect it for use. This is notably the case on the east flank of the chain*, where the mixed and coarse detritus of all the hard rocks, including much greenstone, has at certain spots proved to be auriferous, and in some cases much more so than in others, there being very large tracts indeed where no trace of gold can be detected even in similar detritus.

On the east flank of the South Ural (south of Miask), where the chain is still auriferous, conical igneous rocks have burst out, as represented in the annexed



LAKE OF AUSHKUL, SOUTHERN URAL.

(From a lithograph in 'Russia and the Ural Mountains,' vol. i. p. 359. The 'Holy Mount' of the Tatars is opposite, and the Ural range is seen in the distance.)

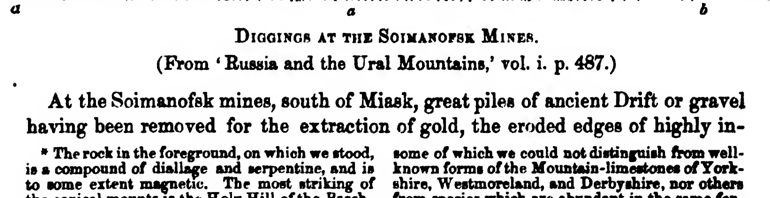
* The reader must recollect that the superficies of all the localities of the Ural Mountains in which gold has been found, united, amounts but to a very small part of the whole chain. Incalculably more diminished is the proportion between rocks which from their nature might be, but are not, auriferous and those of similar structure which really contain gold, when we extend our researches into Central and Eastern Siberia. Thus gold-works are known only at one spot in the western side of the watershed, viz. at Chrestovosdviagensk. It was there that most of the few small diamonds found in the Ural chain were detected, in coarse ancient drift. They were no longer discovered when I visited that place, and traversed the wild wooded chain by the Katchkanar to Nijny Turinsk. See 'Russia-in-Europe and the Ural Mountains,' pp. 391–480.

drawing, and constitute a picturesque scene. The rich grassy low grounds around this Lake of Aushkul, in the country of the Baschkirs, are to some little extent auriferous, the gold having been derived by debacles of former periods, which denuded the surfaces of the slaty and quartzose chain (as seen in the distance), or the adjacent conical hills of greenstone, altered schists, porphyries, syenite, and serpentine surrounding the lake. The slopes and depressions are partially occupied by the gold-bearing débris *.

The extent to which limestones of the Carboniferous age have been altered on the eastern flank of the South Ural is instructively seen at Cossatchi-Datchi, a remote spot visited by my companions and myself, and where also a little gold has been found.

HILLS OF COSSATCHI-DATCHI.
(From 'Russia and the Ural Mountains,' vol. i. p. 439.)

The hills forming the background of this sketch are composed of eruptive rocks and some old schistose strata, whilst in the foreground a little basin is occupied by a number of small conical hillocks of Carboniferous Limestone. Their form and mineralized condition are probably due to the action of gaseous vapours and change of the original substance, since not only the traces of bedding are obliterated, but the limestone has been rendered fetid and saccharoid, breaking upon a slight blow of the hammer. In this case the metamorphic action, however it may have been produced, has just been sufficiently intense to render the limestone as pulverulent as sugar; but it has left numerous organic remains so uninjured that they are easily removed from the matrix †.



DIGGINGS AT THE SOIMANOFSK MINES.
(From 'Russia and the Ural Mountains,' vol. i. p. 487.)

At the Soimanofsk mines, south of Miask, great piles of ancient Drift or gravel having been removed for the extraction of gold, the eroded edges of highly in-

* The rock in the foreground, on which we stood, is a compound of diallage and serpentine, and is to some extent magnetic. The most striking of the conical mounts is the Holy Hill of the Baschkirs ('Russia and the Ural Mountains,' p. 437).

† After enumerating upwards of thirty species of these fossil shells, my companions and myself thus spoke of them:—"Those alone who have the same respect for a true characteristic fossil as ourselves can imagine the feelings of delight with which we here found congregated in one natural Siberian storehouse so great a number of shells, some of which we could not distinguish from well-known forms of the Mountain-limestones of Yorkshire, Westmoreland, and Derbyshire, nor others from species which are abundant in the same formations in Belgium and France! .... Without this discovery we could not have ventured to affirm that many other adjacent masses of crystalline limestone immersed among the granites and trappean rocks of these mountains belonged to similar or associated deposits." ('Russia and the Ural Mountains,' vol. i. p. 44.)

clined crystalline limestones have been exposed, which, being much nearer the centre of the chain than the above, are, I believe, of Silurian age. It is from the adjacent eruptive masses and slaty rocks, *b*, that the gold-shingle, *c* (usually most auriferous near the surface of the abraded rock, *a*), has been derived.

The tops of the highly inclined beds, *a*, are, in fact, rounded off, and the interstices between them worn into holes and cavities, manifestly by very powerful aqueous action. Now here, as at Berezovsk (of which hereafter), Mammoth-remains have been found. They were lodged in the lowest part of the excavation, at the spot to which the small figure of a man is pointing, and at about fifty feet beneath the original surface of overlying coarse gravel, *c*, before it was removed by the workmen from the vacant space under the dotted line. The feeble influence of the existing stream, *n*, in excavating even the loose shingle, is seen at the spot marked *o*, the bed of the rivulet having been lowered by manual labour from its natural level, *o*, to that marked *n*, for the convenience of the diggers.

In some spots the gold-bearing alluvium is a heavy clay; in others it is made up of fragments of quartz-veins, chloritic and talcose schists, and diorite, which lie upon the sides of the hillocks of eruptive rocks *. It was from the infillings of one of the gravelly depressions which I visited, between these elevations south of Miask, that the largest lump of solid gold was taken of which at that time (1824) there was any record †. The diggings by which the gravel or local drift was cleared away from around the vertical masses of rock, the surfaces of which have been so much eroded and channelled out, are expressed in the following diagram.

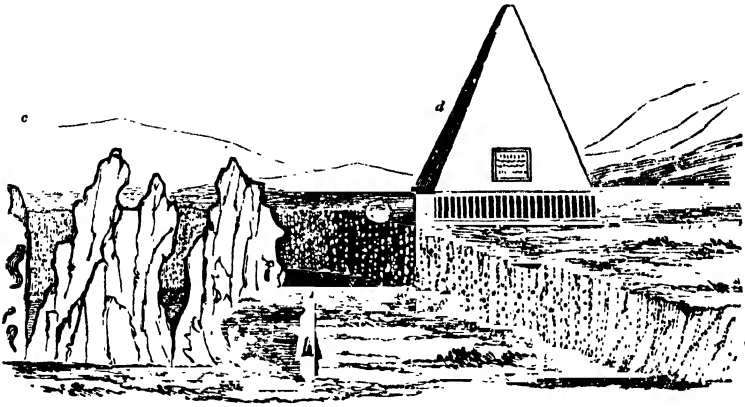
No watercourse sufficiently powerful to support a single block, much less to spread out broad accumulations of such coarse materials, now flows into this upland depression. Nor could the action during millions of years, of such an agency as that of the puny rivulets which now meander in parts of the gravelly low ground, account for the eroded and deeply worn surfaces of the rocks, whether crystalline limestones, quartzites, greenstone, or serpentine. We are thus necessarily compelled, by all the evidences, to adopt the belief that on the Asiatic side of the Ural, as in many parts of Europe, the transport of vast masses of Drift was accompanied by powerful and long-continued aqueous abrasion, most probably marine, of the summits and slopes of the adjacent auriferous hills.

Whatever may have been the period when the rock was first rendered auriferous (and that was certainly long after the formation of the Palæozoic deposits) the date of the distribution of the Uralian gold over the surface is clearly indicated; for the detritus contains in many places remains of the same extinct

* The auriferous shingle, gravel, or sand of the Ural Mountains is poor in percentage in comparison with what has of late years been discovered in California and Australia. Though very large 'pepitas' or nuggets have occasionally been found, much of the auriferous ground considered worth working in Russia, where labour is cheap, and water-power for crushing is everywhere at hand, would, if situated in Australia or California, be little heeded.

† This 'pepita,' weighing ninety-six pounds Troy, is still exhibited in the Museum of the Imperial School of Mines at St. Petersburg. Since the first edition of this book was published, very much larger nuggets have been discovered in Australia. One found in the Mines of Victoria, 120 miles north of Melbourne, and called 'the Blanch Barkly Nugget,' and exhibited in London, weighed 1743 ozs. 3 dwts., or 145 lbs. 3 dwts. Troy, of which 6 ozs. only were estimated as matrix. As the Bank of England was necessarily the purchaser, it was hoped that it would be preserved as the property of that Corporation in the British Museum, and be there viewed as a national treasure, its value being £6905 12*s*. 9*d*.; but, alas! the legal documents by which the Bank Directors are bound necessitate the keeping of all the Bank gold in the cellars of the Bank. A still larger nugget, subsequently discovered, and known as 'the Welcome Nugget,' was found at Ballarat, Victoria: it had a length of 20 inches, breadth of 12, and depth of 7; it weighed 2195 ozs., and fetched £9325. See Prof. Tennant's Supplement to J. Arthur Phillips's paper on Gold-mining &c., Soc. Arts, 1862; and Report Brit. Assoc. 1859, Trans. Sect. p. 85.

fossil quadrupeds as are found in the coarse Drift-gravel of Western Europe. The Elephas primigenius or Mammoth, Bos aurochs, Rhinoceros tichorhinus, with gigantic Stags, and many other mammalia, were unquestionably cotem-

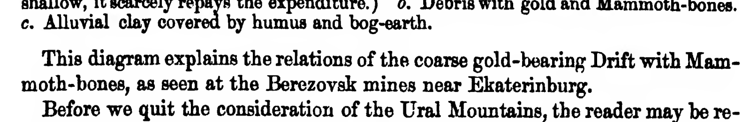


GOLD-DIGGINGS AT ZAREVO ALEXANDROFSK.

a. Ancient rocks, consisting of talc-schist with veins of quartz (the original matrices of the gold), concretionary felspar-rocks, greenstone, &c. *b*. Coarse shingle and gravel, about twelve feet thick, in which the great 'pepita' was found. *c*. Hills from which the chief débris, *b*, was derived. *d*. Pyramid erected to commemorate the visit of the Emperor Alexander the First.

poraneous denizens of Europe and of the Siberian portion of Asia. They appear to have been exterminated, if not simultaneously, at least previously to the existing conditions of the earth's surface in the northern hemisphere, the Bos aurochs being the only one of these huge mammals which, as far as we know, has been preserved to our days *.

GOLD-SHINGLE NEAR EKATERINBURG.



a. Auriferous granite *in situ*. (These rocks contain gold in quartz-veins in the decomposing granite called 'Beresite' by the Russian miners. Herein is the only mine in this chain, or in any part of Siberia, which is worked underground; and, though very shallow, it scarcely repays the expenditure.) *b*. Débris with gold and Mammoth-bones. *c*. Alluvial clay covered by humus and bog-earth.

This diagram explains the relations of the coarse gold-bearing Drift with Mammoth-bones, as seen at the Berezovsk mines near Ekaterinburg.

Before we quit the consideration of the Ural Mountains, the reader may be reminded that, throughout the length of 500 miles, the rocks contain the precious metal at wide intervals, and in limited patches only. Having indicated the geological period when the superficial gold-drift of this region was accumulated,

* The Bos aurochs was probably saved by having inhabited an isolated spot in Western Russia near the forest of Biela vieja in old Poland, where the herd now lives, having there been locally exempted from the causes of that great destruction which befell their associates. This geological view is fully explained by me, accompanied by an excellent account of the Bos aurochs by Professor Owen ('Russia-in-Europe and the Ural Mountains,' vol. i. p. 503 *et seq.*).

let me also here advert to my suggestion concerning the era at which the rocks were impregnated *. It has been already stated that when the metal is found *in situ* it is chiefly in metamorphosed strata of Silurian age, occasionally in Devonian, very rarely in Carboniferous; and it is certain that in the Ural Mountains the gold was segregated in separate masses in these formations at a comparatively modern geological period. In the first place, the western flank of the Ural chain offers clear proof that the process had not been effected when the Permian deposits were completed. During that period vast heaps of pebbles and sand, all derived from a preexisting Ural chain (the older stratified rocks of which had even then undergone much change), were spread out for a length of many hundred miles over the lower country on the west. Together with fragments of all the rocks, sedimentary or igneous, which are known in the chain, specimens of magnetite and copper-ore, large quantities of which abound in the range, are not uncommon in these Permian deposits so largely worked for copper-ore; but nowhere do they contain traces of gold or platinum. Had those noble metals then existed in the Ural Mountains, surely some portions of them must have been washed down together with the iron- and copper-ores, jaspers, and other minerals, and, being indestructible, must necessarily have formed part of the old Permian conglomerates. On the contrary, when the much more modern debacles that destroyed the great animals, and heaped up the piles of gravel just described, affected this chain, then the débris was auriferous. It is manifest, therefore, that the original Uralian rocks were charged with gold during the intervening time—that is, between the Permian period and that of the Mammoth-Drift.

What, then, was probably that geological period in the northern Ural? We cannot assert that it occurred shortly after the Permian era, nor even when any of the Secondary rocks were forming, since no golden débris is found even in any of the older Tertiary grits and sands which occur on the Siberian flank of that part of the chain. If, then, the Mammoth-Drift be the oldest mass of detritus in which the gold of this region occurs abundantly, we are led to believe that in this region the noble metal, carried up by igneous rocks, was only brought together into rich veins at comparatively recent periods. At the same time it is by no means improbable that, where the older rocks are flanked by Secondary deposits, particularly in the South-eastern flank of the Ural chain, where eruptive diorites abound, the fragments of which contain gold, some of these may have been rendered to some extent auriferous after the accumulation of such Secondary strata, as to the south of the Lake of Aushkul (p. 454). In the sequel it will be shown that such operations have occurred during the Secondary periods in South America and California †.

* See the work on Russia and the Ural Mountains, vol. i. p. 472 *et seq.*

† In many instances gold is, I know, associated in the same veinstone with other ores,—such as silver, or argentiferous galena, and various ores of copper and iron—magnetic iron being, indeed, a very frequent accompaniment, whilst the association with tin-stone has before been alluded to. Such occurrences do not invalidate, but strengthen, the view derived from the phenomena in the Ural Mountains; for as copper- and iron-ores are frequently found in old conglomerates or pebble-beds of Secondary age, and lumps of gold have never been detected in them, I see no means (explain the phenomena as we may) of evading the inference that no notable quantity of gold-ore was formed in the Ural Mountains until the comparatively recent epoch indicated in the text. In the work 'Russia and the Ural Mountains,' vol. i. p. 473, the inference is thus stated:—"Whether, therefore, we judge from the total absence of auriferous matter in the ancient [Permian] conglomerates on the west, and in the Tertiary grits on the east, or from the absolute materials in the whole series of regenerated deposits, we conclude that the chain became [chiefly] auriferous during the most recent disturbances by which it was affected, and that this took place when its highest peaks were thrown up, when the present water-shed was established, and when the syenitic granite and other comparatively recent igneous rocks were erupted along its eastern edges."

The reader who wishes to have fuller information on the subject of Uralian and Siberian gold must consult Humboldt's 'Asie Centrale,' and 'Reise nach dem Ural,' &c., by Humboldt, Rose, and Ehrenberg, with the valuable mineral description by M. Gustav Rose, various memoirs by

That the gold occurring in quartz-veins in the solid slate-rocks resulted from an internal igneous agency may well be suggested, if we judge from the appearance which the strings and expansions of the metal indicate as they ramify through the chinks of the hard rock, or from the grains diffused in its mass.

In viewing the widely attested fact that the upper portions of the auriferous veinstones are infinitely richer than the lower parts of the same, I am naturally led to favour the suggestion of Humboldt, that the formation of gold had some closer relation to or dependence upon the atmosphere than that of the baser metals lead, copper, and iron *.

What I contend for, however, is, that, if it had been originally so diffused in the matrix (which seems to be contradicted by the absence of any grain of gold in the original Uralian fragments which compose the Permian conglomerates), still the metal must have been formed into veins, geodes, and strings at a comparatively recent period, and, as I think, by igneous or hydrothermal action from beneath.

Again, the fact is undeniable that, wherever the veinstones in the solid rock have not been ground down by denudation, and remain as testimonials of the original seat of the gold, the portions which have as yet proved to be the richest are those which are at or nearest the surface. Experience too, dearly bought in numberless instances, has taught the miner throughout long ages that as he follows the veinstones downwards by deep shafts into the body of the rock the gold diminishes in volume, so that in many cases the cost of extraction has been greater than the value of the metal. This simple fact is a strong argument against the theory of the formation of gold by a simple aqueous solution, and is manifestly in favour of the igneous origin of the metal, in which I believe.

The points which have been alluded to as drawn from personal observation in the Ural Mountains, are found to have a world-wide application in every tract which has been or is still auriferous. Thus the giant chain of the Andes, which has for ages afforded much gold in its range through Chili, Peru, and Mexico, is essentially of the same composition, though phenomena discovered in South America and in California, since the last edition of this work appeared, have, as will hereafter be shown, modified the generalization. The Indians, who lived in tracts adjacent to those slaty mountains, followed the simple process of picking the shining material from the gravel, sand, and shingle derived from the chain; so that when the Spaniards, the best miners of the sixteenth century, first colonized South America, they naturally inferred that, if ignorant natives could thus gather sufficient quantities of gold to roof the palaces of their sovereigns, they, as skilful Europeans, might extract incredible quantities from the bowels of mountains the mere detritus of surfaces of which had contributed such a vast amount of gold. But, as surely as deep mines frequently enriched the Spanish speculators who sought for copper and silver, so surely gold-mining in the solid rock proved abortive †, owing to the slender downward dissemination of gold in a hard and intractable matrix.

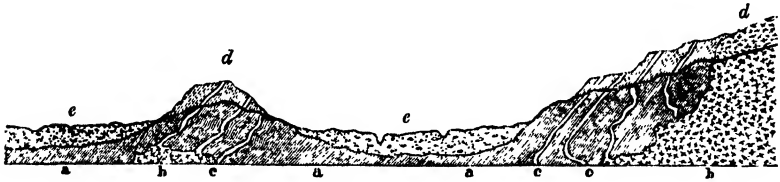
Helmersen and Hoffmann in the 'Annuaire des Mines de Russie,' and Adolf Erman's 'Reise um die Erde,' as well as an account of the general diffusion of gold and a valuable gold-map of the world by that author.

* The eminent metallurgist, Dr. Percy, however, who has detected minute quantities of gold in many lead-ores, has told me that he is disposed to believe that the precious metal may also have been thrown down by deposition from an aqueous medium.

† It has been too much the habit to underrate the capacity and skill of the old Spanish miners, though it is known from Humboldt that during the government of the monarchy in South America many of their works were well conducted;

As the phenomena described are common to many countries, the accompanying diagram is annexed, to convey, as far as possible at one view, a popular idea of the chief conditions under which gold has been formed and afterwards distributed over the surface, so as to be profitably collected by mankind. At the same time, it is not to be accepted as an accurate view of the relations of the veinstones to the strata in which they occur.

IDEAL REPRESENTATION OF GOLD AS FORMED IN VEINSTONES IN ORIGINAL ROCKS, AND ITS SUBSEQUENT TRANSPORT INTO HEAPS OF DÉBRIS.



a. Slaty rocks: the metamorphosed Palæozoic rocks, chiefly of Lower-Silurian age, now in the condition of talcose, micaceous, chloritic, felspathic, or siliceous slates, traversed by igneous auriferous rocks (*b*) and auriferous veinstones, chiefly quartzose, *c*. Above their present dark-lined summits is seen a more lightly tinted outline (*d*), which represents the condition of the auriferous ridges before their former tops were subjected to abrasion, by which great heaps of drifted gravel (*e, e*) were transported from them, covering the adjacent slopes and filling up the gorges and depressions. The highest of these Drifts constitute the 'dry diggings' of the miner,—the lower heaps, in which streams meander, being the 'wet diggings.' As it is impossible to represent in one diagram all the conditions under which gold was originally formed in the rocks, I have merely selected the usual case of veinstones (*c*), the higher (destroyed) portions of which were richer than the veinstones deep in the solid rock.

Gold of Australia.—The extraordinary quantity of gold which has been poured into Britain from her Australian Colonies during the last few years has been chiefly procured, like most of the gold in the other tracts described, from superficial accumulations of shingle, gravel, sand, and clay, derived from the wearing away of adjacent hard rocks, whether of aqueous or of igneous origin.

Having, in the year 1844, recently returned from the auriferous Ural Mountains, I had the advantage of examining the numerous specimens collected by my friend Count Strzelecki along the eastern chain of Australia. Seeing the great similarity of the rocks of those two distant countries, I had little difficulty in drawing a parallel between them; in doing which I was naturally struck by the circumstance that no gold "had yet been found" in the meridional Australian ridge, which in anticipation I termed the 'Cordillera' *. Impressed with

the subsequent operations having been paralyzed chiefly by the political revolutions which have occurred in those countries. If the former trials of Spaniards to procure gold with profit from deep mines in the solid rock, and which were proverbially failures, do not satisfy living speculators, let me refer them to similar results in our day, and trials by our own countrymen. Among these, I would specially allude to the well-known mine of Guadalupe y Calvo, near Durango in Mexico, worked by British skill and capital, where, according to information I received from one of its ablest directors (my friend the late Col. Colquhoun, R.A.), the works, which afforded a moderate profit near the surface, became less productive as the mine deepened, and finally failed altogether—the gold having thinned out, and its place being entirely taken by argentiferous galena. See Quarterly Review, art. 'Siberia and California,' vol. lxxxvii. p. 410.

* The announcement that "no gold had yet been detected," which was printed in my Presidential Discourse, Trans. Roy. Geogr. Soc. 1844, is the clearest proof of my ignorance of a trace of the metal having been discovered by any one. Some time after the practical opening out of the gold mines, however, facts transpired which were totally unknown to me when I ventured upon my comparison. Thus it appeared that Count Strzelecki himself discovered traces of gold in 1839; but, on relating the fact to some friends and to the Governor of New South Wales, Sir G. Gipps, secrecy was enjoined, and the Count never more reverted to the subject, not even in his own work

the conviction that gold would sooner or later be found in the great British colony, I learnt in 1846 with satisfaction that a specimen of the metal had been discovered. I thereupon encouraged the unemployed miners of Cornwall to emigrate and dig for gold, as they dug for tin in the gravel of their own district. These notices were, as far as I know, the first printed documents relating to Australian gold.

At that time California, inhabited only by pastoral Indians and a few missionaries and Spanish herdsmen, was, it will be recollected, equally unknown to be auriferous. Its rich alluvial soil had not then been removed from the surface, and the accident at Sutter's Mill, in 1847, had not exposed the gold in the gravel and shingle beneath it. We can still better understand how this should have been the case with regard to vast tracts of Australia, where similar mineral constants exist, but where, instead of a comparatively advanced people, like the Mexicans or Peruvians, a wretched race, incapable of appreciating the uses of the precious metals, had been for ages the sole inhabitants of a vast continent.

Unwilling to offer what must be a very imperfect epitome of the distribution of gold in Australia, I may, however, be permitted to say a few words on a subject to which I called the practical attention of my countrymen for several successive years previous to the discovery of the gold-fields of that vast region.

At or before that period, geological descriptions of various parts of Australia had been published by Mitchell, Strzelecki, Jukes, &c., without any allusion whatever to *gold*. The Rev. W. B. Clarke did, however, rouse the attention of the inhabitants of New South Wales in 1847 to the auriferous character of these rocks, and indicated, as I had previously done, their similarity to the rocks of the Ural Mountains, including the meridional direction of the two chains. This zealous geologist has since explored the largest range of its gold-bearing lands over upwards of six degrees of latitude, or from the Peel River on the north to the Australian Alps of Strzelecki on the south, where the watershed or Cordillera, rising in Mount Kosciusko to 6500 feet above the sea, trends south-eastwards into the province of Victoria. From this author, and from the voluminous details published for the use of the Houses of Parliament *, as afforded by Stutchbury and others, as well as from the work of Mr. Hargreaves †, who, in 1851, first proved the great value of Australian gold-mining, it was ascertained that the parallel I had drawn in 1844 between the rocks of the chain which I had termed the 'Australian Cordillera' and those of the Ural Mountains is well sustained ‡. Just as in Siberia, the greatest amount of gold is found in

of 1845. It also appears that the Rev. W. C. Clarke wrote to a friend in the colony (1841), mentioning that he had found gold-ore; but this circumstance remained as much unknown to myself and all European men of science as the other. My views, whatever they may be worth, were therefore formed quite irrespectively of any such proceedings, as the following extract from a letter of my friend Count Strzelecki to myself, received whilst the first edition was passing through the press, amply testifies:—"Nothing can give me greater pleasure and comfort at any time than to bear my humble testimony to the inductive powers which you displayed on the occasion of your predictions in regard to the existence of gold in Australia; and consequently I can affirm now, as I did, and do whenever a necessity occurs, that I never mentioned my discovery or supposed discovery of Australian gold to you, prior to your papers on the subject, nor after their publication."

Having disposed of other cases in the first edition, I now simply affirm that no one, whether in Britain or the colonies, had for several years printed anything on the auriferous characters of the Australian rocks except myself, and that my memoirs of 1844, 1845, and 1846 are the earliest publications relating to this subject. See note, first page of this Chapter, for reference to all my works on this subject.

* See 'Blue Books' "Relative to the Recent Discovery of Gold in Australia," presented to both Houses of Parliament, 1852–53. For my own connexion officially with this subject in 1848, see the Papers on the same subject, presented August 16, 1853, p. 43.

† 'Australia and its Gold-fields,' 1855.

‡ Few circumstances have more gratified me than that several of the leading men of New South Wales (including Sir Charles Nicholson and Sir Stuart Donaldson) should, on revisiting England, have testified publicly to the value which was attached in New South Wales to my early comparison of that region with the Ural Moun-

heaps of débris, or old alluvia, derived chiefly from veinstones in old slaty rocks, and often adjacent to or associated with eruptive rocks, whether granites, porphyries, or greenstones. I also assumed that the chief auriferous slaty rocks of Eastern Australia are of the same age as the central masses of the Ural, viz. Lower-Silurian, because, like them, they are overlain in parts by strata which contain Pentameri, Trilobites, and Corals, indicative of the Upper Silurian group. Many of these last have been identified by my friend Mr. Lonsdale, who considers some to be Upper Silurian, and others referable to the Carboniferous era. The shells, examined by Mr. Salter, confirm this conclusion; and the Carboniferous strata, with European forms of life, appear to be clearly separable from the Devonian. Indeed the Lower Palæozoic rocks are here followed by Devonian and Carboniferous strata.

Whilst the most prolific sources in Australia seem to have been the quartzose veinstones which traverse the Silurian slaty rocks, we are further instructed that, as in the Ural Mountains, there are tracts wherein gold is diffused in small particles through the body of granitic rocks *, especially those (according to Mr. Clarke) which are hornblendic or syenitic: the limestones, however, in both countries are partially auriferous only. There is, besides, this striking coincidence between Australia and the Ural: both chains have a main *meridional* direction, the strike of the old slaty rocks and also of the chief gold-veins being from north to south.

In respect to Victoria, which, of all the Australian Colonies, has proved to be much the most productive of gold †, the age of the slaty rocks containing the auriferous veins has been still more clearly determined. Mr. Alfred Selwyn ‡, the Director of the Geological Survey of the Colony, cites the occurrence of numerous Silurian fossils, including Trilobites, Graptolites (Didymograpsus &c.), and Lingulæ, as described by Professor M'Coy. Mr. Selwyn has further recognized, in Victoria, gold-bearing superficial Drifts of three distinct stages, lying above each other, the lowest or oldest of them containing the remains of wood and seed-vessels differing little from the present vegetation. Even the cones of the Banksia, a tree still prevalent in Australia, have been brought home by Mr. Redaway from one of the bottom Drifts, and, being examined at my request, identified as such by the illustrious botanist the late Robert Brown, who first discovered and named the genus. A local distinction in these Tertiary gold-drifts or detrital beds of Victoria is, that they have been overflowed and even interlaced by basaltic coulées, which evidently proceeded from terrestrial volcanos, inasmuch as the vegetable matter beneath them has been charred and destroyed *in situ* by the eruption. This phenomenon, first adverted to by Mr. Selwyn and Mr. H. Rosales, exhibits a strong analogy to what is seen in California §, Mexico, and South America. In all these countries igneous eruptions have burst forth on

tains, and to my prediction respecting the auriferous character of the Australian rocks. At the first Anniversary Dinner of the Australian Colonists from New South Wales, Victoria, South and West Austra'ia, and Tasmania, which took place on the 26th of January 1858, Sir Charles Nicholson, formerly Speaker of the House of Representatives, and also the head of the University of Sydney, asserted, from the Chair, that his brother-colonists agreed with him in the sentiments he expressed; and this opinion he repeated at a public meeting in the Town Hall of Leeds, on the 29th of September 1858.

* See 'Russia and the Ural Mountains,' vol. i. p. 483, where it is stated, "The fact is, then, that though gold has frequently been, and is for the most part formed in quartzose and other veins which have either penetrated or been separated from the mass of the slate formation (and of these the Ural affords countless examples), it has also been diffused in some tracts throughout the whole body of the rock, whether of igneous or of aqueous origin."

† One of the earliest notices of the gold-fields of Victoria is by Mr. G. H. Wathen, in the Quart. Journ. Geol. Soc. vol. ix. p. 74.

‡ See a reference to the successful labours of this geologist in North Wales, p. 82.

§ Mr. J. S. Wilson, who, after a residence in South Australia, passed three years as a goldminer in the Sierra Nevada of California, communicated a memoir on the auriferous rocks of

terrestrial surfaces, at periods posterior to those powerful subaqueous abrasions of the rocks which formed the chief masses of Drift *. Just as in the Ural Mountains (p. 456), these gold-drifts of Victoria, like others described by Mr. Clarke in New South Wales, contain the bones of extinct species of quadrupeds †: in these latter cases, however, the animals are peculiar to the Australian continent.

By consulting Mr. Selwyn's Reports, it will be found that he refers, as above stated, the auriferous Drifts to three periods of time, two of which he considers to be of Tertiary age, and the most recent of modern date and alluvial action. At first sight the reader might suppose that these data are in opposition to my previous statement, that Secondary and Tertiary rocks *per se* have not furnished gold; but such is not the case; for all I assert, particularly in reference to Australia, is, that no veinstones or original segregations of gold worthy of notice have been found in such Secondary or Tertiary rocks (certainly where they are unaltered), but are chiefly confined to the Palæozoic rocks, and especially to the Silurian and their associated igneous masses. The gold-drift which most prevails in Siberia, as in many other countries, is truly a Post-pliocene accumulation, being charged with the remains of extinct Mammalia. The data, however, which are here contributed by the researches of Mr. Selwyn are new to geologists, since they appear to indicate that one of the gold-drifts of Victoria is of Miocene age. Still it was one of those Drifts by the medium of which the gold was abstracted (by what I conceive to have been a powerful denudation) from the parent rock, just as in the subsequent or Post-pliocene time. The peculiar features of the successive distribution of the auriferous Drifts of Victoria are well explained by Mr. Selwyn ‡, and have been beautifully illustrated in his coloured maps and diagrams.

The observations of Mr. John Phillips, a gentleman who, in the year 1847, called my attention to the existence of traces of gold in South Australia (in accordance with my hypothesis), agree generally with those of Mr. Selwyn respecting the rich detrital accumulations §.

The local character of the gold-accumulation of the large Peel-River tract of Australia was closely examined by Mr. Odernheimer, who, uniting the practical habits of a German miner with an intimate knowledge of mineralogy, has shown that there the gold occurs in small quantities only. The thin auriferous quartz-veins lie usually in diorite; and he holds the opinion that the gold results from the decomposition of auriferous iron-pyrites diffused through hornblende-rock, syenite, porphyry, and breccia, as well as diorite. Chromate of iron, hematite, and magnetic iron-ore, as well as several precious stones, have been recognized in that region ||.

that region to the Geological Society of London. From his own observation and experience he affirmed the fact of the downward impoverishment of gold-bearing quartz-veins, and he demonstrated that the richest produce is essentially derived from loose superficial débris.

* In addition to his determination of the age of the original gold-bearing rocks, and the three derivative sediments into which he divides their detritus in Victoria, Mr. Selwyn thus writes to Prof. Ramsay:—"A somewhat remarkable fact, in connexion with nearly all the great granitic masses which I have examined, is that, although they invariably alter the slate-rocks near their junction and send veins into them, they do not in the slightest degree affect the general strike or dip of those beds, but appear to have themselves partaken of the movements which placed those Silurian strata in their highly inclined and contorted positions, and gave them their very uniform meridional direction." He adds, "There is very little slaty cleavage till we get low down into the Llandeilo beds."

† See Rev. W. B. Clarke, Quart. Journ. Geol. Soc. vol. xi. p. 405, where much information is brought together by the author.

‡ See Quart. Journ. Geol. Soc. vol. x. p. 299; vol. xiv. p. 533.

§ See also Rosales on gold-drift below basalt, &c., Quart. Journ. Geol. Soc. vol. xi. p. 397, also the vol. xiv., including valuable notes and memoirs by Mr. Selwyn, Mr. Phillips, Mr. Redaway, and Mr. Rosales.

|| See Quart. Journ. Geol. Soc. vol. xi. p. 399; and vol. xii. p. 287; also a paper on Australian Gems, by Mr. G. M. Stephen, ibid. vol. x. p. 303.

The public of Australia have also, through the Reports of the Mining Commissioners of Victoria, Professor M'Coy, Mr. Selwyn, and other gentlemen *, been made acquainted with the manner in which gold chiefly occurs in the original quartz-veins of the Lower Silurian rocks, whether they be in the proximity of granite or diffused in the gravel derived from such rocks.

While these Reports extended very largely the areas over which it is reasonably inferred that the golden detritus will be found to extend, whether in depressions or on the slopes of the old slaty Silurian rocks (an extent which can only be precisely measured off when adequate geographical maps shall have been prepared), the Commissioners pointed out the reckless and ignorant manner in which many speculators were sinking shafts in proximity to each other in the so-called 'quartz-reefs,' and often missing the vein,—whilst one successful shaft sunk in the right direction, with an adit, would serve the purposes of several proprietors.

They also showed that the evidence given before a select committee of the House of Legislature had been sustained, to the effect that "auriferous drifts must from their very nature be quickly worked out in any one spot." The Commissioners added that they had taken great pains to investigate these points on the gold-fields, and the result had been the most complete confirmation of the evidence alluded to. Some of the old alluvial gold-fields, in full prosperity when that evidence was given, were comparatively deserted when the last edition of this work appeared; and there can no longer be any difference of opinion respecting that class of drifted gold-deposits.

With regard to the evidence touching the yield of gold from deep mining into the 'quartz-reefs,' concerning which there was the greatest scepticism, the same result seemed at first to follow the local inquiries of these Commissioners, who, in a Report signed by their Chairman, said that experience in every country had proved that the yield of gold decreases with the depth where mining in the solid rock had been attempted. An enumeration by name was indeed made of several working shafts which had been abandoned in consequence of finding the gold diminish downwards,—in some cases at a few feet only, in others ceasing entirely, and, again, in a third class continuing downwards in small quantities to about 300 feet. It was then concluded that enough had been stated to vindicate the scientific inference that deep mining in the solid quartz-rock is for the most part unprofitable,—a conclusion which was in unison with my opinion founded on knowledge derived from other gold-countries, as published many years before gold was worked in Victoria: this opinion was again expressed in the first edition of 'Siluria' †.

The knowledge, however, which I subsequently obtained, induced me to modify that view, and particularly as respects the Colony of Victoria. In 1858 I was made acquainted with the opinion of Sir H. Barkly, then the Governor of the Colony, as based upon extensive inquiries and personal observation, which went to show that a much greater supply was then derived from mining in the 'quartz-reefs' than I had supposed to be the case. Again, copies of other Despatches from Sir H. Barkly, with Reports from Mr. Selwyn, accompanied by coloured geological maps and sections prepared by that able geologist, whose observations extend over many years, have led me to think that, if the

* See Report to the Surveyor-General and the Chief Secretary on the Mining Resources of the Colony of Victoria, 1856-7, &c.

† It has recently been found profitable to extract gold at some spots from the veinstones at greater depths; but the gold is more finely and sparsely disseminated than in higher parts of the same veinstones. It is believed that much gold in old detrital accumulations will yet be found under the basaltic coverings of certain tracts, both in Australia and California.—January 1867.

quartz-reefs yet untouched should prove as rich as several which are now yielding fair profits to the miner, the future supply of gold from Victoria will be much more durable than that derived from any other known auriferous country, In fact Victoria is, as far as I know, the richest gold-country of which history records an example, whether we look to the very wide diffusion of the auriferous débris of different ages, which Mr. Selwyn estimates to be spread over 10,000 square miles, or to the quartz-veins in the slaty Silurian rocks, which, by the improved processes of crushing, are forced to yield a supply which could not have been obtained by any of the old methods of extraction (see note, p. 451).

Mr. Selwyn has satisfied himself that the gold-quartz-veins of Victoria are confined to rocks belonging to my original 'Lower Silurian' division in ascending from the Llandeilo formation to those strata, charged with Pentameri, now termed Llandovery rocks. "In every part of the colony," says he, "where such rocks appear on the surface, they are intersected almost invariably in a meridional direction by quartz-veins, from the thickness of a thread to the dimensions of 10 or 15 feet, and in marvellous abundance. Not one per cent. of these 'quartz-reefs' has as yet been touched by the miner; and therefore the chief evidence we have at present of their containing gold is in the richly auriferous and widely spread Tertiary deposits [Drifts] which everywhere accompany them, and which have undoubtedly been derived from their preexisting upper surfaces."

In his highly instructive notes on the Physical Geology and Mineralogy of Victoria, published in 1866, Mr. Selwyn definitely tells us that gold occurs mainly in the quartz-reefs of the Lower and Upper Silurian rocks, and in the detrital accumulations of the Upper Tertiary 'cement' and Drift-deposits, which owe their origin to the abrasion and denudation of the former*. Gold, however, is found occasionally (he states) in sandstone, slate, granite, and diorite. This author admits the axiom I had laid down in former editions of this work, that, "although exceptions are known, it is by most quartz-miners acknowledged, so to speak, as a rule, that the gold becomes finer and finer, and more intimately mixed with the quartz and pyrites, the deeper the reefs are worked." In other words, the larger lumps are always nearest to the surface of the veinstone. The alluvial or drifted gold is said to be generally of finer quality than the 'reef gold,' though the derivation of the former can usually be distinctly traced to adjacent quartz-reefs. Mr. Selwyn propounded an ingenious theory to explain this superiority in the quality of the nuggets in the alluvial gold. He suggested that "particles of alluvial gold may gradually increase in size through the deposition of metallic gold (analogous to the electro-plating process) from the meteoric waters which circulate through the Drifts, and which must have been during the time of our extensive basaltic eruptions, of a thermal, and probably highly saline, character, favourable to their carrying gold in solution." This theory has to some extent been sustained by Mr. Daintree's discovery that wherever woody matter (and it is frequent) is in the Drift, the iron-pyrites in cavities of the wood is auriferous; whilst Mr. Wilkinson has shown by experiment that a nucleus of gold immersed in a weak solution of chloride of gold does receive notable accessions in size when any vegetable substance is introduced into the liquid; but as Mr. Selwyn candidly admits there are still many doubtful points respecting this phenomenon to be cleared up, I prefer to remain in my old belief, that the large nuggets found in the Drift are simply the reliquiæ of the chief masses of gold which once occupied the uppermost parts of the reefs, and that, like the blocks of many an an-

* Notes on the Physical Geography, Geology, and Mineralogy of Victoria, 1866, p. 44.

cient conglomerate, they have been swept from the hill-tops into adjacent valleys by former great rushes of water. In a country like Australia, which, in the later Pliocene period, it is believed, must have been covered by broad sheets of water, and at the same time replete with evidences of intense volcanic action posterior to the formation of gold, we can well imagine that such evolutions may well have been accompanied by rushes of water having great translating-power.

The opinions of such a geologist as Mr. Selwyn, with extensive experience in Britain and Australia *, on the gold-veins and detritus of regions which he has sedulously explored during many years, have had great weight with me, and induced me to modify in the second edition an opinion expressed in the first edition of this work. But, whilst gold-mining downwards to comparatively small depths in the solid veinstones of Victoria may for some years be a profitable business, it by no means follows that adequate profit is there to be maintained at very great depths. The continuous working of deep mines (the law of the downward impoverishment of the metal being admitted) must depend upon the cost of extraction. Thus, in Transylvania and Hungary, where the gold was formerly visible near the surface, the lower portions of the same veinstones now worked afford a very minute quantity only of gold, which (acording to Warington Smyth) would not be worth extraction but for the agency of powerful crushing-mills and the very low wages of the miners.

After showing that the vast areas of granite which in Victoria have been protruded through those old stratified auriferous rocks have had no influence upon their meridional (north and south) direction, or upon their upheaval and contortion, and stating his belief that the cracks and fissures in which the gold-quartz-reefs occur have not been mineralized by any process different from that which has operated in other mineral veinstones, Mr. Selwyn remarks that, "although no very reliable evidence exists of their increasing downwards very greatly in richness, neither is there any evidence whatever in Victoria which would enable us to state that any vein rich at the surface will die out or suddenly become unprofitable."

"There is undoubtedly good evidence," he adds, "that those upper portions of the gold-quartz-veins which have been naturally removed by denudation, and now form the gold-drifts, were often far richer than any we now find at the surface; but in drawing conclusions from this evidence we should not forget that in all probability many hundreds of vertical feet of quartz-veins have been thus naturally broken up, crushed, and washed; and the fact of the veins (so abraded) being still frequently very rich on their present surface goes far, I think, to prove that the diminution of yield in depth, even though admitted to be true on a large scale, is still so slow as not to be appreciable within any depth to which ordinary mining-operations are carried."

Giving several illustrations confirmatory of his views, and showing that the deepest shaft in which a quartz-vein was proved productive reaches to 400 feet, Mr. Selwyn concludes by expressing his opinion "that the extraction of gold from quartz-reefs, if properly conducted, may be regarded as an occupation which will prove as permanently profitable in Victoria as tin- and copper-mining have been in Great Britain"†.

* It gives me great pleasure to reflect that Mr. Selwyn, who has so well executed the important task confided to him, is a scion of the Geological Survey of the British Isles, who greatly distinguished himself in elaborating the difficult relations of the different members of the Silurian and associated igneous rocks in North Wales in company with Professor Ramsay and others.

† It may be here mentioned that the gold-fields of Victoria have afforded tin, a mineral unknown in Russia, which is found not only in the form of sand, but also in small lumps and highly coloured crystals. The reader who wishes to obtain a general view of the most important of the Australian gold-diggings, and acquire an insight into the statistics and social condition of the wonderful

In bowing to the reasoning of a sound geologist, who has so carefully explored our most auriferous Colony, and in modifying my former suggestion respecting the profitless nature of much gold-mining in the solid rocks of Victoria, I still adhere to the belief that, in general, gold-veins diminish much in value as they descend; and I cannot but think that even Victoria affords clear indications of this phenomenon, inasmuch as all the huge nuggets of gold have there been found in Drift derived from the upper portion of the rocks. I have indeed yet to learn that any large lump of gold has been detected in the numerous quartz-reefs now worked in California or Victoria. In all these, as I learn, the gold is disseminated downwards in small grains only *. I am informed by Mr. D. Forbes that the same law exists throughout South America; and according to Mr. Belt this is also the case in Nova Scotia.

One of the most striking examples of successful mining in quartz-reefs was given in a Report of Mr. Selwyn upon the Clunes Quartz-mining-field, about twenty miles north of Ballaarat, and in the occupation of the Port Phillip Company. There it appears that four thin quartz-veins, trending from north to south, and running parallel to each other and to the strata, plunge eastwards in conformity with the strata of the Lower Silurian rock in which they lie, and at a high angle, near the side of a hill, so that the small width of the veined ground, from west to east, is easily traversed by adits from the lower sloping side of the hill. An abundance of water, and every facility for working by means of levels, together with the position of the veins, present a combination of circumstances, as Mr. Selwyn observes, rarely met with in connexion with quartz-veins, and one which will enable these reefs to be worked far more profitably, and at greater depths, than many others in the Colony of Victoria. From recent accounts it would appear that in working downwards even these quartz-reefs or lodes are now found to be less rich in gold.

In thus modifying a portion of my views, I readily admit that, inasmuch as the broken or drifted gold of Victoria has exceeded anything of which we have a record in history, so it is a fair inference that the quartz-reefs in the solid rock of the same Colony, from the higher parts of which the richest drifted materials were derived, may prove more remunerative than those of most other countries.

Looking, however, at the Australian phenomena on a broad scale, there are no essential distinctions between them and the geological relations of gold in the Old World and in America.

The greatest sources of wealth there, as elsewhere, are those depressions which have been filled, or slopes which have been strewed over, with débris from the mountains, whether coarse or fine. The outlines and depths of all these detrital heaps are ascertainable, and the period of their exhaustion may therefore be

Colony of Victoria, should peruse the works of Mr. Westgarth and Mr. Wathen. As regards produce up to a certain period, see also Delesse, Annales des Mines, sér. 5. 1853, tom. iii. p. 185. The true chronicler, however, of all the auriferous returns must refer to the files of the Victorian newspapers, particularly the Melbourne 'Argus.' In this work I cannot enter into details respecting the oscillations in the amount of gold-produce in Australia. These must be sought in the 'Argus' and other Victorian newspapers, and notably in Dickers's 'Mining Record.' In the latter we find an account of much newly discovered drift-gold near Ballarat, under the basaltic coulées. In it also, May 28, 1868, there is an account of a very productive deep mine at Sutter Creek in California, sunk by Mr. Hayward to a depth of 1200 feet, and which is said to prove that the veinstone continues to be richly auriferous. It is, however, to be understood that this shaft has been sunk alongside a wall of granite.

* Subsequent to the large lump, weighing upwards of 145 lb., called the 'Blanch Barkly Nugget,' (see note, p. 456), being exhumed, another mass was found at Ballaarat, weighing more than 184 lb.' Now, as these and all the large nuggets occur low down in Drifts, the facts seem strikingly to confirm my view, that the higher portions of the veinstones, or those first abraded, afforded masses of gold much larger and richer than those finer filaments and grains which, derived from *lower* parts of the veinstone, are lodged in the *upper* detritus.

cient conglomerate, they have been swept from the hill-tops into adjacent valleys by former great rushes of water. In a country like Australia, which, in the later Pliocene period, it is believed, must have been covered by broad sheets of water, and at the same time replete with evidences of intense volcanic action posterior to the formation of gold, we can well imagine that such evolutions may well have been accompanied by rushes of water having great translating-power.

The opinions of such a geologist as Mr. Selwyn, with extensive experience in Britain and Australia *, on the gold-veins and detritus of regions which he has sedulously explored during many years, have had great weight with me, and induced me to modify in the second edition an opinion expressed in the first edition of this work. But, whilst gold-mining downwards to comparatively small depths in the solid veinstones of Victoria may for some years be a profitable business, it by no means follows that adequate profit is there to be maintained at very great depths. The continuous working of deep mines (the law of the downward impoverishment of the metal being admitted) must depend upon the cost of extraction. Thus, in Transylvania and Hungary, where the gold was formerly visible near the surface, the lower portions of the same veinstones now worked afford a very minute quantity only of gold, which (acording to Warington Smyth) would not be worth extraction but for the agency of powerful crushing-mills and the very low wages of the miners.

After showing that the vast areas of granite which in Victoria have been protruded through those old stratified auriferous rocks have had no influence upon their meridional (north and south) direction, or upon their upheaval and contortion, and stating his belief that the cracks and fissures in which the gold-quartz-reefs occur have not been mineralized by any process different from that which has operated in other mineral veinstones, Mr. Selwyn remarks that, "although no very reliable evidence exists of their increasing downwards very greatly in richness, neither is there any evidence whatever in Victoria which would enable us to state that any vein rich at the surface will die out or suddenly become unprofitable."

"There is undoubtedly good evidence," he adds, "that those upper portions of the gold-quartz-veins which have been naturally removed by denudation, and now form the gold-drifts, were often far richer than any we now find at the surface; but in drawing conclusions from this evidence we should not forget that in all probability many hundreds of vertical feet of quartz-veins have been thus naturally broken up, crushed, and washed; and the fact of the veins (so abraded) being still frequently very rich on their present surface goes far, I think, to prove that the diminution of yield in depth, even though admitted to be true on a large scale, is still so slow as not to be appreciable within any depth to which ordinary mining-operations are carried."

Giving several illustrations confirmatory of his views, and showing that the deepest shaft in which a quartz-vein was proved productive reaches to 400 feet, Mr. Selwyn concludes by expressing his opinion "that the extraction of gold from quartz-reefs, if properly conducted, may be regarded as an occupation which will prove as permanently profitable in Victoria as tin- and copper-mining have been in Great Britain" †.

* It gives me great pleasure to reflect that Mr Selwyn, who has so well executed the important task confided to him, is a scion of the Geological Survey of the British Isles, who greatly distinguished himself in elaborating the difficult relations of the different members of the Silurian and associated igneous rocks in North Wales in company with Professor Ramsay and others.

† It may be here mentioned that the gold-fields of Victoria have afforded tin, a mineral unknown in Russia, which is found not only in the form of sand, but also in small lumps and highly coloured crystals. The reader who wishes to obtain a general view of the most important of the Australian gold-diggings, and acquire an insight into the statistics and social condition of the wonderful

In bowing to the reasoning of a sound geologist, who has so carefully explored our most auriferous Colony, and in modifying my former suggestion respecting the profitless nature of much gold-mining in the solid rocks of Victoria, I still adhere to the belief that, in general, gold-veins diminish much in value as they descend; and I cannot but think that even Victoria affords clear indications of this phenomenon, inasmuch as all the huge nuggets of gold have there been found in Drift derived from the upper portion of the rocks. I have indeed yet to learn that any large lump of gold has been detected in the numerous quartz-reefs now worked in California or Victoria. In all these, as I learn, the gold is disseminated downwards in small grains only *. I am informed by Mr. D. Forbes that the same law exists throughout South America; and according to Mr. Belt this is also the case in Nova Scotia.

One of the most striking examples of successful mining in quartz-reefs was given in a Report of Mr. Selwyn upon the Clunes Quartz-mining-field, about twenty miles north of Ballaarat, and in the occupation of the Port Phillip Company. There it appears that four thin quartz-veins, trending from north to south, and running parallel to each other and to the strata, plunge eastwards in conformity with the strata of the Lower Silurian rock in which they lie, and at a high angle, near the side of a hill, so that the small width of the veined ground, from west to east, is easily traversed by adits from the lower sloping side of the hill. An abundance of water, and every facility for working by means of levels, together with the position of the veins, present a combination of circumstances, as Mr. Selwyn observes, rarely met with in connexion with quartz-veins, and one which will enable these reefs to be worked far more profitably, and at greater depths, than many others in the Colony of Victoria. From recent accounts it would appear that in working downwards even these quartz-reefs or lodes are now found to be less rich in gold.

In thus modifying a portion of my views, I readily admit that, inasmuch as the broken or drifted gold of Victoria has exceeded anything of which we have a record in history, so it is a fair inference that the quartz-reefs in the solid rock of the same Colony, from the higher parts of which the richest drifted materials were derived, may prove more remunerative than those of most other countries.

Looking, however, at the Australian phenomena on a broad scale, there are no essential distinctions between them and the geological relations of gold in the Old World and in America.

The greatest sources of wealth there, as elsewhere, are those depressions which have been filled, or slopes which have been strewed over, with débris from the mountains, whether coarse or fine. The outlines and depths of all these detrital heaps are ascertainable, and the period of their exhaustion may therefore be

Colony of Victoria, should peruse the works of Mr Westgarth and Mr. Wathen. As regards produce up to a certain period, see also Delesse, Annales des Mines, sér. 5 1853, tom. iii. p. 185. The true chronicler, however, of all the auriferous returns must refer to the files of the Victorian newspapers, particularly the Melbourne 'Argus.'

In this work I cannot enter into details respecting the oscillations in the amount of gold-produce in Australia. These must be sought in the 'Argus' and other Victorian newspapers, and notably in Dickers's 'Mining Record.' In the latter we find an account of much newly discovered drift-gold near Ballarat, under the basaltic coulees. In it also, May 28, 1866, there is an account of a very productive deep mine at Sutter Creek in California, sunk by Mr. Hayward to a depth of 1200 feet, and which is said to prove that the veinstone continues to be richly auriferous. It is, however, to be understood that this shaft has been sunk alongside a wall of granite.

* Subsequent to the large lump, weighing upwards of 145 lb., called the 'Blanch Barkly Nugget,' (see note, p. 456), being exhumed, another mass was found at Ballaarat, weighing more than 184 lb.! Now, as these and all the large nuggets occur low down in Drifts, the facts seem strikingly to confirm my view, that the higher portions of the veinstones, or those first abraded, afforded masses of gold much larger and richer than those finer filaments and grains which, derived from *lower* parts of the veinstone, are lodged in the *upper* detritus.

estimated approximately. It matters nothing to the statist whether the richest portions of these golden Drifts, or accumulations of broken materials, were for the most part aggregated by causes now no longer in action, which powerfully abraded the surface of the hills (as explained in the previous pages, and particularly in the diagram, p. 460), or whether the diurnal atmospheric action for thousands of years has also been an effective agent. Both causes have unquestionably contributed to spread out and render more accessible a material the search after which in the solid rock is attended with much more difficulty.

In the meantime a basis of all such researches and inquiries into the probable amount of the drift-gold must be provided by good geographical surveys of the auriferous countries of Australia, as completing the work commenced by the late Sir T. Mitchell and his associates. On that important groundwork, geologists may record all progressive observations respecting a region formerly almost exclusively pastoral, but which suddenly became a great and populous centre of commerce through the development of its prolific gold-fields.

In this Chapter I have abstained from alluding to many tracts more or less auriferous, and some rich in produce, which come under the same laws of distribution as those described in the text. Such, for example, are the phenomena of the southern provinces of the United States (South Carolina &c.).

In Canada it was proved, some years ago, that, besides the occurrence of native gold in the Drift-deposits, the metal also occurred in quartzose and metalliferous veins or lodes traversing Lower Silurian strata (the Quebec Group) as well as beds at St. Francis on the Chaudière, supposed to be of Upper-Silurian age.

The supposition put forward by the Geological Survey of Canada (Report, 1863, p. 519), "that the precious metal was originally deposited in the beds of various sedimentary rocks, such as slates, quartzites, and limestones, and that by a subsequent process it has been in some instances accumulated in the veins which intersect these rocks," does not appear to be sufficiently supported by the evidence produced; for no attempt is made to prove that these strata ever contain gold, except at the points of intersection where these metallic veins traverse them, and these veins may fairly be supposed to bring in the gold in question. This would also appear to be the case in the very recent discoveries of gold in the Laurentian rocks in the county of Hastings, at the Richardson's mine, which, from the descriptions of Mr. Sterry Hunt and Mr. Michel (and specially of the latter, who inspected the ground), appears to have been sunk upon a vein of decomposed pyrites containing fragments of an anthracitic mineral, also in a crumbling, decomposed state *, and containing particles of gold disseminated through its substance. The ochreous or earthy matter and oxide of iron are derived evidently from the decomposition of the pyrites, whilst the ferruginous bitterspar may be a secondary product of aqueous action on the neighbouring rock, which is stated to be chloritic. That the gold occurs in the lode itself, and not in the strata, is inferred from the analysis made by Mr. Michel, who states that he found no trace of gold in the rock, except in one case, in immediate contact with the auriferous lode.

The discovery of gold on the Frazer River, in British Columbia, was quite to have been expected, as the ridges between which that river and its affluents flow are simply prolongations of the auriferous chains of California, which are

* Anthracite is frequently found in fragments or nodules in the granite and metalliferous veins of Norway and Sweden. In the granites of Arendal such nodules are generally in a decomposed state, so as to crumble into powder upon the least pressure of the fingers.

(in great part, at least) of Palæozoic age. That a large portion of the northernmost Rocky Mountains, both British and lately Russian, will prove to be auriferous is indeed to be inferred by the discoveries in British Columbia.

Rocks of Lower Silurian age in Nova Scotia have already yielded a notable quantity of gold. It is in the veins traversing the slates and quartzites, and usually coinciding with the strike of the containing beds, just as in Australia. The manner in which these veins conform to the flexures of the beds, as in the curious deposits known as 'barrel-quartz,' indicates that they are of the nature of segregative veins, and cotemporaneous with the disturbance of the beds. This view is corroborated by the occurrence of rolled pieces of the auriferous quartz in the Lower Carboniferous conglomerate (Hartt), while the alteration and disturbance of the auriferous rocks themselves are connected with outbursts of granite. The gold of Nova Scotia is associated with mispickel, copper-pyrites, galena, and blende. Some of the mines have penetrated to a depth of 220 feet, and are very productive, though their capabilities are by no means perfectly tested. The yield of gold in 1865 was 24,867 ounces, according to the Report of the Commissioner of Mines.

Recent discoveries in South America and California have led me to modify, to a certain extent, as before said, my previous opinion concerning the rocks containing gold. Yet, after the explanation I am about to give, it will be perceived that the newer data do not essentially interfere with the general conclusion at which I formerly arrived. In the year 1860, Mr. David Forbes pointed out that eruptive masses of auriferous diorites and greenstones (rocks composed of felspar with hornblende, but devoid of quartz as a normal constituent) had caused the introduction of metalliferous veins or lodes containing gold * into the neighbouring strata of Secondary age, and, to a small extent, impregnated with gold the beds through which they had penetrated—strata which in their normal state were entirely devoid of gold †. Extending his observations in subsequent years, the same intelligent and persevering explorer showed, by observations in Chili, Peru, and Bolivia, that gold had made its appearance in the crust of the earth at two distinct periods, and in both through igneous agency ‡. The oldest he referred to the protrusion of granite amongst the ancient deposits, the younger to the eruptions of diorite or greenstone, which he found had been intruded into and affected rocks of the younger Oolitic period §. To whatever extent this view may be found to accord with observations in other parts of the world, I may here remark that, as regards this comparatively recent appearance of gold (geologically speaking), the observation of Mr. Forbes is quite in accordance with the phenomena recorded by myself and my companions in describing the structure of the Ural Mountains ‖. In that region, as already stated, we had the clearest evidence that the Silurian and other Palæozoic formations of the chain, up to the Carboniferous inclusive, had not been impregnated with gold, as already stated, when the Permian conglomerates and sandstones (which had been derived exclusively from all the Palæozoic, metamorphic, and igneous rocks of those mountains) were accumulated; for, although abundantly charged with iron and copper-ores, these Permian deposits afforded no detritus of gold throughout a length of

* Darwin, in his geological observations on South America, 1846, p. 236, mentions incidentally that in Chili gold and copper-ore are found together in the porphyry-conglomerates at Quillota and Jajuel, and at the latter place also in greenstone, and further remarks that a similar occurrence of gold in copper-ores is seen at Los Hornos, north-east of Illapel, and in the Uspallata range in metamorphosed strata, probably later than the gypseous or Neocomian formation.

† Quarterly Journal of the Geological Society, vol. xvii. p. 31 &c.

‡ Report of British Association, 1865, Trans. of Sections, p. 52.

§ In a communication to the 'Geological Magazine,' vol. iii. Sept. 1866, Mr. Forbes expresses his belief in the general application of these views to all parts of the world.

‖ See 'Russia-in-Europe and the Ural Mountains,' vol. i. p. 475.

not less than 400 miles, and over an area larger than France. As in America, we found gold in the granite of Ekaterinburg, in the syenite of Peschanka, and in the greenstones around Alexandrofsk, as well as in the débris of the quartz-veins which had penetrated the older deposits. Now, as the granitic and dioritic rocks of the Ural were unquestionably emitted at different periods, it follows that the data laid before geologists nearly a quarter of a century ago are so far in harmony with the observations of Mr. D. Forbes. At the same time, although we gave clear proofs of the comparative recency of the production of gold in the Ural Mountains, we did not prove, as he did, that the latest of these auriferous impregnations or emanations was posterior to the formation of the Secondary rocks. It is, however, quite possible that future observers, who have more time at their disposal than we possessed, may discover that the greenstones and porphyries which have penetrated the Jurassic rocks in the Southern Ural have also impregnated them with a small amount of gold.

The newest or post-Jurassic origin of gold is also that to which attention has recently been attracted by Mr. Whitney, a well-known geologist of the United States, whose work on California * is replete with excellent observations on the physical geography, geology, and natural history of that country. The following conclusion of this author cannot, however, be allowed to pass without a comment. After showing that some gold is found in altered strata of Triassic, Jurassic, and Cretaceous age, which are in contact with, or adjacent to, auriferous granite, he says, "While we are fully justified in saying that a large portion of the auriferous rocks of California consist of metamorphic Triassic and Jurassic strata, we have not a particle of evidence to uphold the theory that has been so often maintained, that all, or even a portion, of the auriferous slates are older than the Carboniferous..... We are able to state, referring to the theory of the occurrence of gold being chiefly limited to Silurian rocks, that this metal occurs in no inconsiderable quantity in metamorphic rocks belonging as high up in the series as the Cretaceous" †. I presume that Mr. Whitney applies this view to California only; for he must be aware, without quitting his own vast continent, that the chief seats of gold, in North as well as in South America, are in the quartz-veins of slaty rocks for the most part older than the Devonian rocks, and that all these cases agree with the ascertained facts in Australia, New Zealand, Asia, and Europe, and even in all the well-examined tracts of Eastern North America. Denying that I have been warped by any theory in my former attempt at a generalization on this subject, and declaring that I was guided solely by the facts then known to me, I have at the same time much satisfaction in acknowledging the additions made to that knowledge, first by Mr. D. Forbes, and recently by Mr. Whitney and his associates.

Yet, no one who peruses the work of our Transatlantic cotemporaries can fail to see that several of the phenomena are still involved in obscurity, and that some of them even tell against the novel portion of their conclusions. For example, in the early part of the volume in which the Coast Ranges are described, and in which cinnabar and copper are shown to be worked amongst metamorphosed Secondary and even Tertiary and eruptive rocks, it does not appear that gold has ever been profitably worked in these extensive ranges north and south of San Francisco, although many varieties of highly metamorphosed Secondary rocks, up to the Cretaceous inclusive, occur in them, jaspers, ser-

* Geol. Surv. California: Geology, vol. i. 1865.

† Silliman's Americ. Journ. s. 2. vol. xxxviii p. 281. With regard to the 'auriferous slates' of California, Mr D. Forbes has called my attention to a series of specimens, some of which appear to me to prove most distinctly that these so-called 'slates' are merely shales altered and impregnated with gold and other metallic compounds in the manner described by him. (See also Geological Magazine, vol iii Sept 1866.)

pentines, and mica-schists abounding in beds of the age of the Chalk. In the only situation, however, where gold-mining had been carried on to some extent in connexion with presumed Cretaceous rocks, the author avows that the age of these (metamorphic) rocks has been referred to the Cretaceous rather from general (lithological) analogy than from any direct evidence of fossils (p. 196). In the Genessee Valley, however, there are placer-workings on rocks containing Jurassic fossils (pp. 308 & 482); and in the Mariposa County a large quartz-vein, forming the Mount Bullion Ridge, and containing at some points gold enough to pay for working, crops out among hard shales and sandstones judged to be of Jurassic age from the Belemnites and other fossils found in them* (pp. xx, 226, & 482). Nevertheless it is only when the geologist traverses the wide longitudinal valley which separates the above-mentioned Coast Ranges from the great and much loftier Sierra Nevada, that he meets with those richly auriferous slates from which the great wealth of California has been derived†. Now several passages in Mr. Whitney's work clearly show that the chief body of these auriferous slates is of Palæozoic age; he even exhibits sectional diagrams representing the Cretaceous and other Secondary conglomerates, shales, and sandstones as lying quite unconformably upon the edges of the vertical slaty gold-rocks (see pp. 211 & 354). Again, all the fossils found in the massive limestones which are intercalated in the upper portions of these auriferous slates being well known Carboniferous types, must not the inferior slates be of Devonian and Silurian age? In various other passages descriptive of the highly metamorphosed sedimentary strata of various ages in California, up to the Miocene Tertiary inclusive, we perceive what vast difficulties any geologist must have had to encounter in drawing distinct conclusions as to the age of many parts of these rocks; but we do learn that in most cases the igneous rocks of the region, particularly the granites and diorites, are in themselves auriferous. Respecting the difficulties the author himself candidly says, "It was not possible to find any locality where these metamorphic rocks and the unaltered Cretaceous could be seen in contact; and some difficulty was met with in clearly making out whether the metamorphic rocks might not themselves be of Cretaceous age. The weight of evidence, however, seemed to be decidedly in favour of the auriferous rocks being older than the Cretaceous" (p. 322).

Seeing, therefore, that no other fossils have been detected in the richly auriferous slates of the Sierra Nevada save those of Palæozoic age in the limestones, and that the association of gold-quartz with the Jurassic rocks of California is very rare, I can as yet see no valid reason to induce me to alter materially the generalization I adopted in my former editions, as derived from evidences in various parts of the world, viz. that the Silurian and associated Palæozoic strata, together with the igneous rocks which penetrated them, have been the main recipients of gold. At the same time, I admit that small quantities of gold have, in Western America, been eliminated during the Secondary period; but these I consider to be exceptions to a general though not universal rule.

The chief facts remain, therefore, as stated in my former edition. The general axiom which I would now further lay down is, that as no aqueous deposit of Primary, Secondary, or older Tertiary date has been ever found to contain gold

* The Jurassic fossils at the gold-diggings of the Genessee Valley, California, were found in 1863 by Messrs. Brewer and King. In the Mariposa County, Jurassic fossils were found by Miss Errington in 1864, and others by Messrs. King and Gabb. Professor Blake, who noticed Miss Errington's fossils in 1864, had already in 1863 recognized an Ammonite (in Mr. Spear's Collection) from the American River, where gold-quartz-mining has been carried on: see his 'Catalogue of the Minerals of California,' 8vo, Sacramento, 1866.

† Mr D. Forbes has expressed to me the opinion that not one-tenth part of the gold of South America is found in the veinstones which have been intruded among the Secondary rocks.

in its unaltered original matrix, it seems to follow that certain rocks of igneous origin must have been the gold-producers, by impregnating with the metal the contiguous sedimentary matter which they metamorphosed. I further believe that, even in tracts which are largely auriferous, and in which the granites and igneous rocks have only here and there risen to the surface (as in Victoria and the Ural Mountains), the auriferous quartz-veins are the results of the same igneous action.

Conclusions.—The facts and arguments insisted upon in the preceding pages lead to these conclusions:—

1. That, looking to the world at large, the auriferous veinstones in the Lower Silurian rocks contain the greatest quantity of gold.

2. That where certain igneous eruptions penetrated the Secondary deposits, the latter have been rendered auriferous for a limited distance only beyond the junction of the two rocks.

3. That the general axiom before insisted upon remains, that all Secondary and Tertiary deposits (except the auriferous detritus in the latter) not so specially affected never contain gold.

4. That as no unaltered purely aqueous sediment ever contains gold, the argument in favour of the igneous origin of that metal is prodigiously strengthened; or, in other words, that the granites and diorites have been the chief gold-producers, and that the auriferous quartz-bands in the Palæozoic rocks are also the result of heat and chemical agency.

In reviewing the facts already elicited respecting the origin and age of the various metals most useful to man, I am led to believe that iron is the oldest as well as by far the most diffused in nature. In fact, it occurs plentifully in the most ancient of all known aqueous deposits, the Laurentian rocks, and has continued to be abundant throughout all the strata up to the formation of the bog-ore of the present day. Copper was, I think, the next in age, since, unlike the diffused iron, it is found in veinstones which have traversed the ferruginous Palæozoic rocks long after their consolidation. Lastly, judging from the evidences presented to us over such an enormous area as that which is occupied by the Permian deposits in the western or European flank of the Ural Mountains (p. 458), and knowing that they contain much copper-ore mixed up with the débris of the Palæozoic and igneous rocks of that chain (but without a trace of gold or silver in them), I conclude that those noble metals could not have been then evolved in that chain.

Now, if in disparagement of this view it should be alleged that these and other metals were occasionally met with in the same veinstone, and that therefore they may have been formed simultaneously, I reply that such collocation may be easily explained. Assuming that these ores have been connected with igneous agency acting from beneath, it necessarily follows that in their emission the last-formed ores of gold and silver would occasionally intermix in their passage with the ores of iron and copper

which had been previously disseminated in those sediments through which the molten matter charged with the nobler metals had to pass.

Whether the penetration of gold into the crust of the earth was confined to two epochs, as suggested by Mr. D. Forbes, must be worked out by close survey of many auriferous regions; but of this we are certain, that, even after the first appearance of this metal, at each detrital accumulation, during Tertiary periods and even to our own times, the gold has been washed down into hollows with the débris of the rocks in which it was formed. Hence the various ages of golden gravels or Drifts, whilst not a trace of the precious metal has ever been found in conglomerates or sandstones of Palæozoic or Mesozoic age. No stronger proof than this can be given of the truth of my inference that gold was the last formed of the metals.

Notwithstanding the preceding sketch, it would ill become any geologist to attempt to estimate, at this day, the amount of gold which remains undetected in vast regions of the earth as yet unknown even to geographical travellers, still less to speculate upon the relative proportions of it in such countries. At the same time, the broad features of the case in all known lands may be appealed to, to check extravagant fears and apprehensions respecting an excessive production of the ore; for we can trace the boundaries, rude as they may be, of a metal ever destined to remain precious on account of those limits in position, breadth, and depth by which it is circumscribed in Nature's bank. Let it be borne in mind that no gold has ever been found in unaltered Secondary and Tertiary rocks, which occupy so large a portion of the surface, and that mines sunk to great depths in the veinstones of those rocks in which it does occur have hitherto, with rare exceptions, proved unremunerative. The only cases in which very deep mining in the solid matrix repays are chiefly those where the rocks are soft, or the price of labour low. Further, it has been ascertained that, whatever may have been the agency by which this impregnation was effected, the metal has been chiefly gathered together in rich veinstones towards their surface. It is by the abrasion and dispersion of these veinstones that the richest golden materials have been spread out, in limited patches, and generally near the bottom of basin-shaped accumulations of detritus.

Now, as every heap of these broken auriferous materials in foreign lands has just as well-defined a base as each gravel-pit in our own country, it is quite certain that hollows or slopes so occupied, whether in California or Australia, must be dug out and exhausted in a greater or less period. In fact, all similar deposits in the Old or New World have had their gold abstracted from heaps the areas of which have been traced, and their bottoms reached; and the same result has, as I anticipated in the last edition of this work, been already to a great degree realized in Australia. Not proceeding beyond the evidences registered in the stone-book of Nature, it may therefore be affirmed that the period of such exhaustion

in each country (for the deposits of detritus or fields of diggings are mu shallower in some tracts than in others) will, in great measure, depe on the numbers and activity of the workmen employed in each localit Numerous hands, used with Anglo-Saxon energy, in California and Aus tralia may in a quarter of a century accomplish results which could b attained only in many centuries by a scanty and lazy indigenous popula tion; and thus the present large flow of gold into Europe from such tract must, in my opinion, diminish as soon as the auriferous detritus of certai tracts has been well sifted and the richest or upper parts of the veinstone have been worked out.

In defining the general character of the most productive auriferous rocks, the geologist must, however, necessarily admit a number of exceptions to any prevailing rule; for, whilst the chemist, as before said, has recently detected minute traces of gold in lead- and copper-ores, the researches of the practical miner have taught us that in any auriferous region where certain quartzose lodes are surcharged with ores of iron, particularly the oxides and sulphurets, some amount of gold will probably be found. Again, the diffusion or dissemination of small particles of gold throughout the body of various igneous rocks, and also, to some extent, in altered Secondary rocks of aqueous origin, is, as before said, clearly ascertained. Humboldt, indeed, asserted long since, that in Guiana, "gold, like tin, is sometimes disseminated in an almost imperceptible manner in granitic rocks, without the ramification or interlacing of any small veins" *; and we now know that this phenomenon is general along the chain of the Andes. In Mexico the gold-mine of Guadalupe y Calvo, before alluded to (p. 460, note), was in porphyry. In Australia (district of Braidwood, and other places south of Sydney), a peculiar variety of felspathic granite is described as being permeated by small particles of gold; and David Forbes has shown, as above stated, that it is present in diorites as well as in the granites of South America. In Siberia, Hoffmann † has spoken of its distribution in such minute quantities in clay-slate that it was only by pounding up large lumps of the rock that any perceptible quantity could be extracted; whilst I have pointed out its occurrence in the granite, syenite, greenstones, and altered Silurian rocks of the Ural Mountains (p. 454).

In all regions, therefore, where auriferous rocks occur, we may find gold either in the coarse débris of Tertiary and Quaternary ages, or in more modern alluvia. Felspar and quartz being the chief component parts of the veinstones, we can easily imagine how their former destruction on a large scale would leave as a residue large heaps of that pipe-clay (the decomposed felspar), or those gritty pebbles (the abraded quartz), which, with the accompanying ores of iron (particularly the black magnetic oxide), are so frequently the gold-bearing matrices in the Drift of auriferous countries.

* Voyages, vol. ii. p. 238.
† Reise nach den Goldwäschen Ost-Sibiriens: St.-Petersburg, 1847.

Whilst it is an admitted fact that gold has sometimes been so diffused in minute and imperceptible particles in certain rocks, we know of no case, I repeat, in which the gold contained in veinstones increases in volume as you descend into the body of a mountain. On the contrary, the indisputable fact is, that the chief quantities of gold, including all the considerable lumps and pepitas, have been found imbedded in the upper parts of the veinstones, and have been broken up and transported with the débris of the mountain-tops down the slopes and into adjacent valleys.

In closing these remarks, let me express my opinion that the fear that gold may be greatly depreciated in value relative to silver (a fear which at one time seized upon the minds of some people) seems to me to be unwarranted by the data registered in the crust of the earth; for, looking to all the recent discoveries, my readers may be assured that gold is much the most restricted (in its native distribution) of the precious metals. Argentiferous lead, on the contrary, expands so largely downwards into the bowels of the rocks, as to lead us to believe that it must yield enormous quantities of silver for ages to come—and the more so in proportion as better machinery and new inventions shall lessen the difficulty of subterranean mining*. It may indeed well be doubted whether the quantities both of gold and silver procured from regions unknown to our progenitors will prove more than sufficient to meet the exigencies of an enormously increased population and our augmenting commerce and luxury. But quitting this theme I would simply say, as a geologist, that Providence seems to have adjusted the relative value of these two precious metals for the use of man, and that their relations, having remained the same for ages, will long survive all theories. Modern science, in short, instead of contradicting, only confirms the truth of the aphorism of the patriarch Job, which thus shadowed forth the downward persistence of the one and the superficial distribution of the other:—"Surely there is *a vein* for the silver . . . . . The earth hath *dust of gold*"†.

* A Report from the late Colonel Lloyd (Journ. R. Geograph Soc vol xxiii p. 196) showed to what a vast extent silver might yet be extracted from the South-American mines This was, indeed, the view taken long ago by Humboldt, who expressed to me his conviction that the produce of silver will be much augmented, reminding me how tracts in Spain which contained rich silver-mines in the days of Hannibal had recently proved to be highly productive.

† The Book of Job, chap. 28.

CHAPTER XX.

OBJECTS OF THE WORK.—GENERAL VIEW OF ANCIENT LIFE FROM ITS EARLIEST TRACES.—PROGRESS OF CREATION, AFTER A LONG INVERTEBRATE PERIOD, TO THE FIRST PERIOD OF FISHES, FOLLOWED BY THE EARLIEST EPOCHS OF LIZARDS AND MAMMALS.—GREAT FORMER CHANGES OF THE SURFACE, AS PROVED BY FRACTURES, DISLOCATIONS, AND REVERSALS OF STRATA.—SUCH GREAT MOVEMENTS INEXPLICABLE BY REFERENCE TO MODERN CAUSATION.—GENERAL VIEW OF PALÆOZOIC SUCCESSION RESUMED.—CONCLUSION.

THE main object of this work has now been accomplished; for I have laid before the reader a history of those types of former life which, by the labours of geologists, have been found to occupy distinct stages in the oldest deposits composing the crust of the earth. In all this there is no theory, but simply an accumulation of positive data. The order of such successive generations is indeed much more clearly proved than many a legend which has assumed the character of history in the hands of man; for the geological record is the work of God.

Placed as the fossils are in their several tiers of burial-places the one over the other, we have in them true witnesses of successive existences, whilst the historian of man is constantly at fault as to dates and even the sequence of events, to say nothing of the contradictory statements which he is forced to reconcile.

In this volume I have passed rapidly over the earliest stages of planetary matter, for these must necessarily be for ever involved in much obscurity; and respecting the earliest condition of the crust of the earth, I simply inferred it was then in so molten a state that no life could have existed. The sketch of ancient nature consequently began with a description of the oldest known stratified rocks in which traces of life have been detected. The Laurentian rocks (chiefly gneiss) of North America, Britain, Bavaria, Bohemia, and possibly of Scandinavia, forming the foundations on which all the other strata have been accumulated, were characterized as containing specimens of the lowest grade of animal life, in the shape of a marine Foraminifer, the Eozoon.

It was then pointed out that the next succeeding deposits, or those of Cambrian age, though of enormous dimensions, and often but slightly altered mud and sand, contained only the rarest trace of anything higher in organization than a Zoophyte.

Next it was shown that the following (or Silurian) formations exhibited even in their very bottom-beds a considerable augmentation of animal life, as shown by the presence of Crustaceans, Mollusks, and Zoophytes, occupying layers at similar horizons in the crust of the earth in very distant

regions. Proceeding upwards from the earliest of these zones, we then ascended to other sediments, in which we recognized a more copious distribution of marine creatures, closely resembling each other, though imbedded in rocks separated by wide seas, and now often raised up into the loftiest mountains. Examining all the strata exposed to view that were formed during the first long natural epoch of the life which I termed 'Silurian,' we found that the successive deposits were charged with a great variety of forms—such as the Trilobite or primeval Crustacean, with a few of the earliest Chambered Shells, as well as numerous exquisitely formed Mollusks, Crinoids, and Zoophytes,—the families of Cystideans and Graptolites being exclusively found in these Silurian rocks. In short, examples of every group of purely aquatic animals, save Fishes, have been assembled from those ancient Lower Silurian sediments.

Though we are now as well acquainted with the contents of the Palæozoic rocks as with those of Mesozoic age, the multiplied researches during the last thirty-two years have failed to detect the trace of a Fish, amid the multitudes of marine beings, in the various sediments which constitute the great mass of Silurian rocks. Of these animals, though they are the lowest in the scale of the great division 'Vertebrata,' we are unable to perceive a vestige until we reach the 'Ludlow' zone of the Upper Silurian, and are about to enter upon the Devonian period. In fact, when I last wrote, the few Cartilaginous Fishes of the uppermost Silurian formation still remained the most ancient known beings of their class* (see Pl. XXXV.),—a generalization which was first established by my own researches† in 1835.

Looking, however, at the Silurian System as a whole, and judging from the collection of facts gathered from all quarters of the globe, we know that its chief deposits (certainly all the lower and by far the most extensive) were formed during a very long period in which, while the sea abounded with countless invertebrate animals, no Bony Fishes had been called into existence. The Silurian (except at its close) was consequently an epoch in which there appeared no example of that complete bony framework in which, as approaching to the vertebrate archetype, the comparative anatomist traces the first step in that series of creations which ended in Man‡.

Whether, therefore, the term 'successive' or 'progressive' be applied to such phenomena, I assert that all the evidences derived from close and long-continued researches have demonstrated that there was an enormous

* The only addition to our knowledge on this point since I made the announcement of 1855 is, that the genus Pteraspis has been found in the Lower as well as in the Upper Ludlow rock.

† See 'Silurian System,' p. 605.

‡ See Owen on the Homology of the Vertebrate Skeleton. Reports Brit. Assoc. Adv. Science, 1846, p. 169. The general reader will find a powerful essay, embodying the opinions, I believe, of the same high authority, on the proofs of a progression in creation, in the Quarterly Review, 1851, p. 412 *et seq.* The arguments there employed have been strengthened by subsequent discoveries alluded to in this volume. I would also specially refer the reader to Professor Sedgwick's 'Discourse on the Studies of the University of Cambridge' for a masterly and eloquent illustration of several of the views which are here advocated.

period in the history of the world wherein no vertebrated animal lived. In this sense, the appearance of the first recognizable fossil Fishes, towards the close of the Silurian period (and then they were cartilaginous and rare), seems to be as decisive a proof of a distinct creation as the placing of Man upon the terrestrial surface at the end of the long series of various animals which successively characterized the preceding geological periods.

Nor have we been able to disinter from the older strata charged with Invertebrata any distinct fragments of Land Plants. In the very same uppermost Silurian stratum, however, wherein the small early Fishes have been found, there also do we observe the first clear appearances of Trees.

If it be granted that the position of the earliest recognizable Vertebrata is sound evidence on which to argue, still it may be contended that such forms may at a future period be found in still lower strata. In this work, however, I reason from known data only. Nor is it on such testimony alone, strong, clear, and universal as it is, that my argument is based; for as soon as we pass into the formation immediately overlying, and quit the zone wherein the first few Fishes have been detected, we are furnished with collateral proofs that this was the earliest great step in a successive order of vertebrate creation which was never afterwards interrupted. In the following (or Devonian) period we are surrounded by a profusion of large fossil Fishes, with vertebræ sometimes ossified*, and with dermal skeletons of very singular forms,—all differing considerably from anything of their class in the succeeding epochs. It is thus clear that these Fishes were marked additions to the preexisting forms of marine life. Again, in this Devonian era we are presented with well-defined Land Plants, also of larger dimensions than the rare specimens in the uppermost Silurian.

Just as the introduction of Cartilaginous Fishes is barely traceable towards the close of the long Silurian era, so, becoming afterwards much more abundant in the Devonian rocks, they are thenceforward abundantly associated in the Carboniferous and all younger formations with true Osseous Fishes and with Reptiles, the remains of which are found intermixed with the other products of the land and sea.

Putting aside theory, therefore, and judging solely from observation, we fairly infer that during very long epochs the seas were unoccupied by Fishes, that the earliest discoverable creatures of this class had very rarely an osseous vertebral column, and, lastly, that in the succeeding period the Fishes having bony vertebræ appeared in greater numbers, and became ever afterwards abundant in the overlying deposits. Do not these absolute data of the geologist, resulting as they do from the most minute

* A Coccosteus with true bony vertebræ has recently been found by Mr. C. Peach, and added to the Museum in Jermyn Street

as well as the most general researches, afford clear signs, in this respect, of a progress in creation?

In the Silurian era, as will presently be insisted on, there are countless proofs of shores; and yet there is not a trace of a Land Plant, washed from the adjacent lands, until we reach the uppermost limits of the system. The signs of terrestrial produce, augmenting in the Devonian epoch, become universally abundant in the Carboniferous period, as marked by a copious terrestrial flora. This earliest luxuriant tree-vegetation, the pabulum of our coal-fields, is also specially remarkable for its spread over many latitudes; and together with it occur the same common species of marine shells, all indicating a more or less equable climate from polar to intertropical regions,—a phenomenon wholly at variance with the present distribution of animal and vegetable life over the surface of the planet. Together with the earliest profuse land-vegetation Reptiles first appear, and thus substantiate the proofs of another rise in creation.

Lastly, while the Permian era was distinguished by the disappearance of the greater number of the primeval types, and by essential modifications of those which remained, it still bore a strong resemblance, through the genera of its plants and animals, to the Carboniferous period; whilst, in unison with all the great facts elicited by our survey of the older strata, it was typified by the appearance of an animal of a high grade—the Proterosaurus, a large Thecodont Reptile, allied (according to Owen) to the living Monitor.

In speaking of the Silurian, Devonian, Carboniferous, and Permian rocks, let me however repeat that, whilst each of the three latter groups occupies wide spaces in certain regions, the Carboniferous alone approaches to the value of the Silurian in representing length of time, or succession of animal life in the crust of the globe. When the Silurian System was first divided (1833-34) into lower and upper parts, our acquaintance with younger formations merely sufficed to show a complete distinction between its fauna and that of the Carboniferous rocks, from which it is separated in England by the thick accumulations of the Old Red Sandstone. At that period the shelly and slaty rocks of Devonshire were not known to be the equivalents of such Old Red Sandstone; still less had the relations and fossil contents of all the strata now called Permian been ascertained. Judging from the fossils collected, it was then, however, stated that the Lower Silurian contained organic remains very distinct from those of the Upper Silurian; and yet I united the two groups in a system, because they were characterized throughout by a common *facies*. This was called a 'system' because it was characterized by a profusion of the peculiar animals Trilobites, Cystideans, and Graptolites, together with Orthides and Pentameri of types wholly unknown in the Carboniferous rocks: and, whilst Fishes were seen to exist in the intermediate masses of Old Red Sandstone, no traces of them could be detected below the uppermost zone

of the Silurian rocks. Thirty-three years have elapsed since these data were first indicated, and, after vigilant researches in various regions of both hemispheres, these great features remain the same. The labours, indeed, of those who followed me have infinitely more sustained the unity of that system; for its lower and upper divisions are now proved to be connected by a marked community of generic types and analogous forms.

Let me here, therefore, and before the superior formations are alluded to, recall attention to the Fourteenth and Fifteenth Chapters (on Scandinavia, Russia, and Germany), in which it has been shown (on the authority of de Verneuil, von Keyserling, Barrande, Kjerulf, Schmidt, and others) that the Lower and Upper Silurian rocks of those countries constitute one united mass. On this head I cited in the last edition (as giving a general conspectus of such comparison) my own conclusions as given in a memoir on this subject, read in 1857 before the Geological Society of London. I there showed* (and, indeed, the proofs are to be seen in previous Chapters) that, in Scandinavia, Russia, and Germany, the Lower and Upper Silurian rocks constitute a natural system, and that often in tracts where the deposits are of very small dimensions compared with those of Britain, the abundance of characteristic fossils is remarkable.

Those of my cotemporaries who may still adhere to the belief that the 'Primordial Zone,' which Barrande has shown to be the base of Silurian life (and all the American authorities take the same view), ought to be separated from it and placed in the Cambrian system, must be first referred back to the natural sections of Norway, Sweden, Bohemia, and North America abroad, as well as to those of North and South Wales at home, to prove the intimate transition and passage (mineralogical and zoological) of that lower zone into the strata of Llandeilo age. No more remarkable exhibition of this geological union can be seen than on the sea-cliffs in Whitesand Bay, Pembrokeshire. There the Tremadoc Slates of the 'Primordial' Silurian zone are seen to be not only symmetrically parallel to, but (as in North Wales) gradually passing up into slates of absolutely similar structure in which the Lower Llandeilo fossils appear. The lower and upper masses of the cliffs are, in short, so intimately united that any lithological division between them is impracticable.

Whilst such is the physical union of these rocks, I have it now in my power to add the evidence produced by the long-continued researches of the veteran geologist Dr. Bigsby, who, in his valuable 'Thesaurus Siluricus,' shows that, in taking a general view of the distribution of what he has classed as Silurian life, no less than twenty-seven forms are found to be common to the 'Primordial' and overlying Silurian zones†.

In a broad classification of primeval life, the late eminent naturalist

* Quart. Journ. Geol. Soc. vol. xiv. p. 36.

† This work of Dr. Bigsby will be shortly published, and the author is, I am happy to learn, to be aided in bringing it out by the Government Grant Committee of the Royal Society. The outline of the 'Thesaurus' and its chief objects are explained in a memoir read before the Royal Society. (See Proc. Roy. Soc. vol. xv. p. 372.)

Edward Forbes considered that the Silurian rocks constitute the Lower Palæozoic,—the Devonian, Carboniferous, and Permian rocks the Upper Palæozoic; but whether this ancient series be divided into two or into three classes (some palæontologists preferring to hold the Devonian as a separate and intermediate type,—the Lower and Upper Silurian rocks constituting truly an older natural system, just as the Carboniferous and Permian deposits form a younger one), the result of the researches of the numerous authors appealed to in this volume has unquestionably justified the application of the more comprehensive term 'system' to the Silurian rocks.

At the close of the Permian or Supra-Carboniferous era, an infinitely greater change took place in organic life than that which marked the ascent from the Silurian system to the overlying Palæozoic groups. Nearly, if not quite, all the species of the earlier races then disappeared, and were replaced in the Trias by a new series, the types of which were continued through those long epochs which geologists term Secondary or Mesozoic (the 'mediæval age' of extinct beings). In these, again, the reader will learn, by consulting the works of numerous writers, how one formation followed another, each characterized by different creatures,—many of them, however, exhibiting near their downward and upward limits certain fossils which link one reign of life on to another.

Whilst it is beside my present aim to enter upon descriptions of such Secondary deposits (still less of those called Tertiary, which intervened between the Secondary rocks and the sediments of the present day), we may still cast a glance over the general order admitted by all geologists, to see how it harmonizes with what has been related of the succession of animals belonging to the older rocks, and as also indicating a progression from lower to higher grades of life.

Let me, then, again remind the reader that he has been presented in this volume with clear proofs of an immensely long period having elapsed during which, with countless remains of nearly all other inhabitants of the sea, no trace of a Fish has been discovered, to represent the prototype of that vertebrate succession which terminated in Man. Next he will have noted that, after Fishes first appeared, long ages elapsed before a Reptile was added to the creatures of the epoch; and then we have seen that, notwithstanding the demonstration of the frequent submergences of enormous breadths of land, clothed with a rich and copious vegetation on which Insects fed, no sign whatever has been met with, in the spoils of these well-explored Carboniferous and Permian domains, that they were inhabited by a single Mammal!

Proceeding upwards into the Secondary strata, the earliest traces of Mammalia are first detected in the uppermost member of the Trias (the Rhætic beds or upper part of the Keuper Sandstone of Würtemberg, which

covers the Muschelkalk and lies at the base of the Lias). In the 'Bone-bed' of that formation the relics of a small marsupial Mammal were found by the late Dr. Plieninger, who named it Microlestes antiquus. Again, the late Dr. Ebenezer Emmons, of the United States, described from the lower beds of the Chatham Coal-field, North Carolina (of the same age as those of Eastern Virginia, and probably of the Würtemberg Keuper*), the jaw of another minute Mammal, which he called Dromotherium sylvestre. Mr. Charles Moore also detected in an agglomerate filling the fissures of the Carboniferous Limestone, near Frome, Somersetshire, and composed chiefly of the débris of Rhætic beds (uppermost Triassic), small teeth and bones closely resembling those of the Microlestes antiquus of Germany†.

Lastly, Mr. Boyd Dawkins, of the Geological Survey, has discovered a Mammal's tooth in the Rhætic strata forming reefs exposed at low water at Watchet, Somerset‡.

Ascending from the Keuper or summit of the Trias, we have to traverse the whole of the Lias and the Lower Oolitic formations (which are charged, at intervals, with many terrestrial vegetable remains and highly organized Saurians, unlike the Reptiles which preceded them) before we find another trace of mammalian life. Insects, which, as has been shown, first appeared in the era of the earliest great forests (Devonian, p. 439), became more abundant in these Secondary rocks; and with these are found the bones of that oldest known winged Reptile, the Pterodactyle. Still, surrounded as we are in these strata by Plants, Insects, and many Reptiles, we have to journey through several of the Secondary deposits before we obtain other evidences of the existence of Mammalia than a few jaws and fewer vertebræ of the little Marsupial Phascolotherium Bucklandi (Broderip) of the Stonesfield Oolite §, and its (possibly placental) companions Amphilestes, Amphitherium, and Stereognathus.

Passing upwards through the higher Oolitic deposits, and rising considerably in the scale of formations,—where, in short, we are about to take leave of the Oolitic or Jurassic group, and are entering into the mass of the great estuarine formation, the Wealden, and approaching the base of the Cretaceous rocks, there it is, as might have been anticipated, that geologists have discovered proofs of the existence of many more Mammals than have been detected in any of the Lower Secondary deposits. Through researches which began under the direction of Edward Forbes, and which a few years ago unfolded great fossil wealth to the labour and acumen of Mr. Beckles, a perfect mine of highly organized small Mammalia was opened out in the

* I cannot admit that the beds in which the small Mammal Dr. Emmons described were entombed can be referred to the Permian group, or close of the Palæozoic era. The absence of Permian Mollusks, now known in other parts of North America (see p. 470), invalidates his view, and I have yet to learn that Sir C. Lyell or any geologist would consider the beds in question to be older than the Keuper of Germany. Dr. Emmons's views respecting the supposed Permian age of the Chatham coal are also criticised in Professor R. Jones's 'Monograph of the Fossil Estheriæ' (Palæontographical Society), 1862.

† See Professor Owen's description of the vertebræ, Quart. Journ. Geol. Soc. vol. xvi. p. 492.

‡ Quart. Journ. Geol. Soc. vol. xx. p. 409.

§ It was in the year 1827 that the 'Didelphys Bucklandi' was described by that sound naturalist, my friend the late Mr W. Broderip (Zoological Journal, vol. iii. p. 408).

cliffs near Swanage. Though it is not in my power to enter into details illustrative of the characters of these curious little animals *, some of which have been described by that great authority, Owen, I may refer the reader to a lucid memoir by the late Dr. Falconer, in which, besides describing his Plagiaulax Becklesii and Pl. minor, referred by him to herbivorous or frugivorous Marsupials, such as Hypsiprymnus Gaimardi †, he announced that the three Purbeck genera known up to that time were Spalacotherium and Triconodon, Owen, and Plagiaulax, Falconer. He further stated his belief in the existence of "at least seven or eight genera of Mammalia, some of them unquestionably Marsupialia, both predaceous and herbivorous, and others of them," he said, "conveying to my mind the impression, so far as the evidence goes, that they belong to the Placental Insectivora, having affinities more or less remote to existing types" ‡.

Willingly granting to Sir C. Lyell great credit for having anticipated the advent § of the Mammals disinterred by Mr. Beckles, I must be permitted to say that, in my opinion, this discovery does not in any way invalidate the general inference of an advance in creation, as based upon the broad data reiterated in this work, and derived from observation in many parts of the world.

Let me entreat the reader not to be led, by the reasoning of physiologists, and through any appeal to minute structural affinities, to impugn the clear and broad facts of a succession from lower to higher grades of life in each formation. Let no one imagine that, because the bony characters in the jaw and teeth of the Purbeck Plagiaulax are "such as the comparative anatomist might have expected to find among existing Marsupials," and the animal is therefore far removed from the first or embryonic idea of the archetype, or is a specialized rather than a generalized form, such an argument disturbs the successional order of distinct Classes as seen in the crust of the earth.

Leaving, however, the physiological doctrine to be worked out by others, I repeat that the Stonesfield and Purbeck discoveries are directly in accordance with the views of those geologists who, like myself, recognize distinct proofs of the successive appearance of each great Class of Animals. The reader must therefore recollect that, whilst the most laborious endeavours during the last thirty-three years have failed to detect the trace of a Mammal in the earlier formations treated of in this volume, the Purbeck strata, in which the remains of minute creatures of that class are first found in abundance, are *as modern* in the eyes of a 'Palæozoic' inquirer, as they are venerable in the estimation of the geologist whose studies of the

* One of these little creatures was stated by the late Dr Falconer to be of about the size of the Pigmy Flying Opossum. I was informed by Dr. Falconer that he found among the Purbeck fossils collected by Mr Beckles abundant remains of a Thecodont Saurian, to which he applied the designation of Saurechumodon. We thus learn that the mere presence of a Thecodont Saurian is no proof of the age of the deposit, since remains of this family of Reptiles range from the Permian to the termination of the Oolitic series.

† Quart. Journ. Geol. Soc. 1857, p. 261.

‡ *Loc. cit.* p. 262.

§ See 'Manual of Elementary Geology,' 3rd edit. p. 236.

earth's crust have been mainly directed to those Tertiary rocks in which, for the first time, in mounting from older to newer strata, we meet with a great variety and profusion of Mammals, of all sorts and sizes, many of them, indeed, still being the associates of Man. In such Tertiary formations, we have, indeed, before us on all sides the bones of the higher orders of Mammalia, drifted from numerous adjacent lands, and associated with the exuviæ of marine creatures, which, though scarcely more abundant than those of the earlier formations, are all of different species.

Animals, in short, of every class, whether terrestrial or marine, and particularly Mammalia, abound more and more in each succeeding formation of Tertiary age, exhibiting an increasing quantity and variety of both sea and land creatures as we approach the superficial accumulations. In these only are entombed the bones of such gigantic mammals as the Mammoth,—quadrupeds which once inhabited our present continents, and which must have required for their sustenance a range over lands probably as extensive as those occupied by Man and his associates. Of Man we have no traces until after the Glacial Period, or the last of the great physical changes before the present configuration of the earth's outlines was determined.

Let the reader dwell on these remarkable facts which the close labours of geologists have elicited in this century. Let him view them in the clear and broad order indicated by Nature, advancing from an Invertebrate to a Vertebrate era, and next mark a regular rise thenceforward in the numbers and organization of animals by the addition, in successive epochs, first of Reptiles and then of Mammals. Let him execute a patient survey from the lower deposits upwards, and he will find everywhere a succession of creatures rising from lower to higher organizations,—a doctrine promulgated by the illustrious Cuvier, but from infinitely less perfect data than we now possess *.

Yet, however they admit the facts, some of my cotemporaries think that they can so explain them as to reject a belief in successive creations from lower to higher classes. They suppose that nearly all the strata of date antecedent to those in which the first signs of life have been detected are often in so crystalline a state that, if they originally contained remains of animals, the traces of them must have been obliterated by changes since effected in the structure of the rock. Now, if this supposition had been supported by the researches of late years, we must doubtless have admitted that all evidence of the earliest creation has been buried in a hopeless obscurity; but this difficulty (which I never underrated) has been quite set aside by the discovery of the Eozoon in those highly crystalline rocks which form the basement of every known formation. Then, again, above these fundamental strata we find, as before explained, deposits many

* The Palæozoic or primeval fossils were necessarily little known to that great comparative anatomist, who drew his conclusions from data within the scope of the knowledge of his day, i. e. from the higher orders of Vertebrata which appear in the more recent epochs only, and specially those of the Paris Basin.

thousands of feet thick, and scarcely at all altered, which, made up of sand, mud, and pebbles, constitute the very foundation of the fossil-bearing Silurian strata. In these huge lower sediments, only a doubtful genus of Zoophyte with traces of Annelides or Worms have been found, and portions of a Trilobite (p. 28); whilst chemical analysis has afforded independent proofs that phosphoric acid, a true indicator of former life, is hardly to be detected in these rocks, though it abounds in the fossiliferous Silurian strata. If this argument were derived from the evidences collected in one region only, it might have been suggested that, as the same formation which is barren in life over one district teems with signs of it in another, so the Cambrian rocks elsewhere may still prove to be more fossiliferous; but such infra-Silurian rocks have been well explored in many countries, and even when unaltered have not yet afforded the scanty signs of life which have been wrung from them in Britain. Lastly, the discovery of the little Foraminifer Eozoon in the Laurentian rocks strengthens prodigiously the other inferences previously arrived at by evidence from so many parts of the earth, knowing as we now do that the lowest grade of animal has alone been detected in the oldest of all rocks. Be it also recollected that this, the only additional evidence obtained in this branch of our inquiry during the last seven years, supports the view of successive creation which I have long maintained.

When we proceed upwards into the Lower Silurian strata, replete with clear and well-defined groups of all marine animals except Vertebrata, an antagonist might possibly reply that Gelatinous Fishes, devoid of backbones (like the solitary little Amphioxus now living), may have been the only creatures of their class which swarmed in the then existing seas,—and, if so, that no traces of them were likely to exist, their boneless bodies perishing and leaving no sign of their former existence. As an old student of Nature's works, I cannot, however, allow this hypothesis to outweigh the numerous well-recorded facts which announce the coexistence and perfection of all the other classes in the ancient marine areas. If thousands of invertebrate animals have left their coverings behind, and the most delicate impressions of their parts, is it rational to suppose that, if Fishes then existed, every part of their framework should be wanting which, whether consisting of dermal plates or of vertebræ, characterizes them in the strata of all succeeding epochs? Nay, more, we have even in the Silurian strata fossil reliquiæ of such soft animals as Starfish; and if so, why not those of the imaginary boneless fish of the theorist? But the stony records are not silent as to what were the predaceous animals of the ocean before the creation of Fishes, properly so called; for we see that in this same long period, in which no traces of Vertebrates prevailed, there was an abundance of Cephalopods; and as creatures of that structure are well known to be carnivorous, we have a fair right to assume that they were the appointed tyrants of those Silurian seas.

Another hypothesis which has been advanced in opposition to the mass of positive evidence is, that, although such earlier rocks are void of Ichthyolites, the sediments may all have been formed in limited zones around the earth; just as it is believed by some naturalists that there are seas subject to certain currents and conditions of the bottom in which no Fishes are now living. Here, again, the application of such a theory is still more negatived by the facts adduced. Silurian rocks similar in structure, and containing the same organic remains, are not confined to any one segment of the earth's surface, however broad, but are largely developed in nearly all known regions. The argument is therefore untenable in face of the knowledge we have acquired, that, amidst a profusion of all the other forms of marine life, Fishes and other Vertebrates are absent from strata formed in the seas of this early age.

The prevalence of a widely spread primeval ocean, and the existence of a land-surface not yet subjected to such variations of outline as have since brought about and modified the different climates of the earth, when connected with a belief in the former greater radiation of heat from its interior, are the chief data required to satisfy us that in the Silurian period physical conditions prevailed with which the nature and extensive spread of the earlier groups of animals are in harmony.

Admitting that in the remote periods during which the earliest accessible sediments were accumulated, large areas of land (though probably of comparatively little altitude), as well as vast rivers, must have existed as sources of the primeval deposits, we may still well believe that such lands were separated by wide seas, and that hence we ought necessarily to meet with a smaller number of littoral animals and a greater number of oceanic forms. Taking advantage of the great prevalence of the supposed pelagic forms, some persons have suggested that we may have as yet discovered only the deep-sea products of the Silurian period, and that, when the true edges of its lands come to be detected, we may then find Plants and many creatures now unknown to us. To this I reply that many proofs have already been adduced of lands which were contiguous to the marine Silurian sediments, both Lower and Upper, and even to the earlier Cambrian. Innumerable pebble-beds, coral-reefs, and trails of animals that crawled upon the tide-marked mud, are the principal evidences required; and to these I will again presently advert *.

It has also been said that the great number of floating shells, particularly the Orthocerata, which abounded in the Silurian era are in themselves indicators of deep seas, remote from land, into which, therefore, terrestrial spoils were little likely to be transported. Now the Silurian Chambered Shells may, indeed, have required a certain depth of water; and yet many of them, like the Nautilus pompilius of the present day, might

* These proofs are so numerous that in a recent essay Agassiz treats of all the fossils of the [illegible] as having been accumulated on what he calls 'The Silurian Beach'.

have lived at no great distance from the land of that time: and, in the succeeding Carboniferous Period, when the Mountain-limestone was formed, we find no lack of floating shells and other Mollusca equally characteristic of certain depths of water; and yet these are associated with abundance of Plants which were drifted from land, simply, as I would say, because the earth then bore a rich arboreal vegetation. In the earlier Silurian time, however, notwithstanding the certain existence of contiguous lands at that period, we can discover only feeble traces of vegetable tissue. In all the subsequent formations of the geological series, from the Permian upwards, Land Plants ever accompany marine remains. Thus in the Lias and Oolites, for example, we meet with an equal, if not a greater number of floating shells than in the Silurian rocks (the Ammonites and Belemnites of that younger period, requiring the same depth of water, had taken the place of the primeval Orthocerata); and yet, associated with them, we have everywhere proofs of the proximity of the land, in the abundance of fossil Plants and wood derived from *terra firma*, doubtless then very much more extensive and diversified than in the earliest times.

If the old continents and islands which existed during the accumulation of the Lower-Silurian deposits had borne trees, the numerous researches of geologists in all quarters of the globe must have brought to light some signs of them; for, whilst we know that there are rocks of considerable extent which, from the fine nature of their materials, may probably have been deposited in an ocean at some distance from a shore (though we have as yet little or no evidence as to the accumulation of sediment in deep seas, where no currents prevail), there are, on the other hand, many Silurian districts of the Old and New World where the form and structure of the strata bespeak the action of waves and surge, and where the imbedded Sea-weeds, Zoophytes, and other remains compel us to adopt the same view. If, also, the primeval fauna does afford fewer Spiral Univalves than are seen among the animals of the 'Laminarian Zone' of modern seas, we may suggest that shore-lines, as we understand them, must have been much less numerous in primeval epochs than in the Tertiary period and at the present day, after the surface had been diversified by lofty dividing ridges on the land and corresponding depressions in the ocean. With this important reservation, however, we obtain as many of those signs of shores as we can expect to find in the earlier deposits. Appeal, for example, to some of the oldest sedimentary deposits in which traces of any living thing have been detected, the Longmynd rocks of Britain, and see, in their mode of aggregation, in the Sand-worms which burrowed into them, and in the rain-drops which dibbled their surface, the clearest proofs of shore-accumulation (p. 28).

Again, look to the illustrations of this point furnished by the American geologists, from a very wide extent of their country, where the strata are nearly horizontal, and where, without any ambiguity, our kinsmen have

traced life downwards in the successive crusts of the earth, to the same 'Primordial' Silurian zone as their cotemporaries have done in Britain*, Scandinavia, and Bohemia. The American geologists have evidences, in their lowest Silurian (Potsdam) beds, of numerous trails of animals, probably Crustaceans, by which a film of mud or sand formed by one tide was tracked and burrowed before another covered the impressions, and left them to future ages as proofs of layers deposited on the shores of former lands. Again, in other Silurian beds of the far West, there exists the same abundance of Coral-reefs as in Britain, and the still stronger evidence of pebbly and sandy shores which never contain the trace of a Land Plant. Why, therefore, wander from such plain facts into theory? And why not admit (what is, indeed, in accordance with all we have observed) that nearly all the Silurian era had passed away before Trees grew upon the land or Fishes swam in the waters? The Silurian rocks extend over areas as large as, if not larger than, any great systems of the following periods; and yet in them alone of the whole geological series is there, I repeat, an entire absence of an arborescent vegetation derived from the then adjacent lands.

Here it is well to remind the student of the wide, if not universal, spread of the primeval strata (including many igneous rocks which were associated with them). We may suppose that when such extensive Palæozoic sea-bottoms were raised into lands the former continents, from which the sediments had been derived, were submerged and disappeared. Be this as it may, we know that in all quarters of the globe Silurian or older strata constantly lie in juxtaposition to the other overlying Palæozoic formations; and hence it is impossible to apply to the lower strata any reasoning which does not also refer to those which repose upon them; for, as the Silurian rocks are constantly found in the same latitudes as the Devonian and Carboniferous, why is it that in enormous masses of the one there are never found traces of Vertebrata and Land Plants, and that in the very same region remains of both these classes abound in the other? By no theoretical suggestion, therefore, can the fair inference be evaded that things which did not exist during the Laurentian, Cambrian, and Silurian periods appeared in the same zones of the earth during the following ages.

The Uniformitarian, who would explain every natural event in the earliest periods by reference to the existing conditions of being, is thus stopped at the foundation-stones of the great natural edifice, each story of which has been inhabited by different creatures. Nature herself, in short, speaks to him through her ancient monuments, and tells him that, though she has worked during all ages on the same general principles of destruc-

* Mr. Salter has described a trail of Hymenocaris vermicauda, in the Lingula-flags of North Wales ('Lowest Silurian' of the Geological Survey): see Quarterly Journal of the Geological Society (May 1854), vol. x. p. 208. Other tracks also are common in these beds.

tion and renovation of the surface, there were formerly distributions of land vastly different in outline from those which now prevail. The primeval sediments were penetrated by outbursts of great volumes of igneous matter from the interior, the violence of which is made manifest by many clear evidences. Fractures in the crust of the earth, caused by earthquakes that suddenly removed masses to positions far above or beneath their previous levels, were necessarily productive of such powerful translations of water as abraded and destroyed solid materials, and spread them out over continents, or altogether swept them away, by operations infinitely surpassing any changes of which the historical era affords examples.

I could here cite the works of many eminent writers for numerous evidences of the grander intensity of causation in former epochs, by which gigantic stratified masses were sometimes inverted, or so wrenched, broken, and twisted as to pass under the very rocks out of which they were formed. Among those who have passed away, I may mention de Saussure, von Buch, Humboldt, Cuvier, Brongniart, Buckland, Conybeare, De la Beche, and W. Hopkins. Of those who hold the same views and are now living, I may enumerate Élie de Beaumont, d'Archiac, de Verneuil, Studer, Sedgwick, J. Forbes, Phillips, Dana, Logan, and many others. The traveller amid the Alps and other mountain-chains will there see clear and unmistakeable signs of such former catastrophes, each of which resulted from fractures utterly inexplicable by reference to any of those puny oscillations of the earth which can be appealed to during historical times.

On this point of the former intensity of causation, I must so far depart from the immediate object of this work, or the history of the successive Palæozoic races, as to dwell briefly on some of those physical changes which have affected the surface at various periods in the whole range of geological succession.

I may say that I never examined any extensive area without recognizing evidences of fracture, displacement, and occasionally inversion of the strata, which no amount of gradual, continuous action could possibly explain. Thus, on the northern face of the Swiss and Bavarian Alps *, and occupying a range of hills upwards of 100 miles long, Miocene conglomerates and shelly shales, which doubtless once reposed on Eocene beds, so abundant in the adjacent mountains, and which once dipped away into the lower grounds, are now seen to plunge at high angles under the very rocks on which they once rested, and from which they have been derived; the intervening Eocene formation having entirely disappeared along this great line of fracture and inversion.

See the deep chasm occupied by the Lake of the Four Cantons (between Brunnen and Altdorf)—a profound transverse fissure, with vertical cliffs on either side, and observe the broken and discordant ends of the strata on the

* Journ. Geol. vol. v. pp. 158 &c.

one side, showing abrupt, clean, vertical abscission from those of the other. Then follow up, on each opposite cliff, the twisted and often inverted lines of torsion by which the Tertiary strata are crumpled up with the Secondary rocks, particularly on the east side of that great hollow, even to the summit of the mountain.

Let the traveller proceed to the other parts of this convoluted and broken chain, and gaze on the grandeur of the metamorphic action by which bands of fossiliferous limestone have been transmuted suddenly in their horizontal range into crystalline gypsum; and then let him ask himself if he believes that the agency which produced such enormous and abrupt changes was of no greater intensity than that which prevails in our times. Undoubtedly the *vera causa* of metamorphism is still present, since we see that, at the Baths of Aix in Savoy, in the western Alps, and at other places, the sulphuric acid, when liberated from the mineral water, does produce a film of gypsum on the surface of the limestone walls; but how believe that the agent which in our day works on a scale of inches in many years, is of the same intensity as that which operated throughout a whole range of lofty mountains? how are we to explain that, by gradual operations, the strata composed of carbonate of lime through a thickness of thousands of feet are all at once, and on the same horizon, changed from bottom to top into sulphate of lime?

Let it not be supposed that we, who hold to the proofs of more powerful causation in ancient periods, do not fully admit that the former physical agencies were of the same nature as those which now prevail. We simply assert, on the countless evidences of fracture, dislocation, metamorphism, and inversion of the strata, and also on that of vast and clean-swept denudations, that these agencies were from time to time infinitely more energetic than in existing nature,—in other words, that the metamorphisms and oscillations of the terrestrial crust, including the uprise of sea-bottoms, and the sweeping out of débris, were paroxysmal in comparison with the movements of our own era. We further maintain that no amount of time (of which no true geologist was ever parsimonious when recording the history of bygone accumulations of sediment, or of the different races of animals they contain) will enable us to account for the signs of many great breaks and convulsions which are visible in every mountain-chain, and which the miner encounters in all underground workings.

If slow and uninterruptedly gradual risings of land from beneath the sea, or depressions beneath it, had taken place during any one even of the recent geological periods during which the earth has undergone many changes, ought we not to see repeated evidences of such former out-swellings in the presence of sea-shells and pebbles and marine débris extending in slopes on many sides of continents and islands, from the sea upwards to considerable heights? Instead of such signs, of which no example has been indicated, we constantly find that even in the latest geological times, whether

called Quaternary or Post-pliocene, the former sea-beaches or marine shelly deposits of those days usually lie either in separate terraces or in patches at distinct and different altitudes, varying from a few feet above the sea-line to great altitudes, as at Moel Tryfane in North Wales, where existing Arctic shells lie at upwards of 1300 feet above the sea. These evidences demonstrate that such oscillations were not caused by a continuous and equable expansion or contraction of the crust, but by intermittent agencies of sudden activity following long periods of repose. They are, in short, proofs of a former intensity of causation, as contrasted with the uncertain signs of gradual elevation or depression that are appealed to as having occurred within the historic era. The case therefore stands thus. The shelly and pebbly terraces which exist are signs of sudden elevations at different periods; whilst the theory of modern gradual elevation and depression is still wanting in any valid proof that such operations have taken place except within very limited areas. Much longer and more persistent observations must indeed be made before any definite conclusion can be reached respecting the rate of gradual elevation or depression which has been going on in the last thousand years, though we may confidently assert that such changes in the relations of land to water in the historical period have been infinitesimally small when compared with the many antecedent geological operations.

One of the reasons which has been adduced in favour of long and gradual changes is that on the coast of Norfolk there exists a submarine preglacial forest, where the stems of the trees are still standing erect, with their roots in the ancient soil in which they grew. That ancient soil is covered by other younger deposits, including the Drift, and in it are found bones of Elephants, Hippopotami, and other animals, and of other extinct and living Mammalia*. Now, so far from seeing in this commixture, and in the vertical stumps of trees, the indications of long and slow action, I view them as evidences of a sudden movement.

When examining a similar submarine forest, with the trunks of the trees still erect, the late eminent Dr. Forchhammer, of Copenhagen, came to the conclusion, as he informed me, that the movement by which they were submerged must have been sudden. He argued that the rapid immersion of the trunks, and their having been quickly surrounded by marine mud, could alone have preserved them; for if the trees had been gradually sinking at the rate of an inch or two in a year, they would have been entirely decomposed under the atmosphere long before their submergence, and thus no trace of their trunks would have remained.

Wherever we see an enormous quantity of the fractured bones of common land animals huddled together, as in many cases, with those of huge Hippopotami, I naturally infer that we have in this admixture good proofs of a catastrophic destruction of such animals. As one example of this phe-

* Lyell, Elements of Geology, 6th edit. p. 160.

nomenon, I have cited the mixed and angular flint- and bone-drift with remains of Stags, Mammoths, and Hippopotami on the flanks of the chalk cliffs of Brighton *.

Then, if we pass from the subject of elevation or depression of lands to that of their denudation, how can the believers in the power of the gradual action of the sea explain the wonderful results of erosion which present themselves on the surface of rocks of all ages? For if we look to the agency of present seas, we know that the deep ocean never erodes, and that, on the contrary, perfect tranquillity reigns at its base. If, then, denudation in our time is produced only by breakers or by waves acting on coast-lines, which have, we know, a wasting and denuding power over limited regions, how account for the perfectly clean sweep which has been made of wide tracts? With the exception of ordinary submarine currents, to which many continents must have been subjected, what more natural method of explaining these facts than by referring them to the translation by vast bodies of water suddenly put into action by those upheavals of parts of the earth of which we have clear evidence? Judging from the fact that marine gravel and shells do often lie in terraces, at different altitudes on the sides of our mountains, must it not in fairness be admitted that each of the upward sudden movements leaving such a terrace must have given rise to waves of such magnitude and force as would sweep over and scour the low tracts, destroying land animals in their course, and mixing them up with those of aquatic habits? How explain the mixture of bones of all sorts of animals except by some such catastrophes? I do not here invoke any violation of the laws of nature. I only ask practical geologists to look at the proofs we possess of sudden dislocations and upheavals of the land, and then reflect upon what must have been the corresponding effects of the water displaced. How account for the tons of fractured bones of Hippopotami, huddled together, as we know, in crevices and caverns of the rocks of Sicily, except by some such violent action? Let not beginners in geology be led away by those who, deriding 'convulsionists' and 'catastrophists,' repudiate data which many men who have passed their lives in the study of the dismemberments of the rocks think are inexplicable without appealing to much more powerful causes than any of which history records an example.

Has the advocate who would account for all such dismemberments by long continuance only of existing causes, whether by the active erosion of breakers on a shore or by atmospheric action, ever satisfactorily accounted for the complete and entire denudation of our clean-swept 'valleys of elevation'? Let him inspect that British model of such phenomena, the Silurian valley of elevation at Woolhope, first described by myself †. What agency, I ask, except that of very powerful currents of

* See my Memoir thereon, Quart. Journ. Geol. Soc. vol. vii. pp. 349 &c.

† See 'Silurian System,' p. 427. After alluding to the removal of the enormous masses of Old Red Sandstone which must formerly have covered this insulated valley, and to the clean sweep of all

water could have removed every fragment of the débris that must have resulted, whether at one or several periods of elevation, from the destruction of all the once superposed arches of rock, and have scooped out all the detritus arising from such destruction, from the circling depressions, the central dome, flanking ridges, and former cover of those Silurian strata? And if that water had not been impelled with great force, caused by sudden uprises of these rocks from beneath the Old Red Sandstone, what other agency will account for so complete a denudation, the broken materials having only found issue by one lateral gorge, which was, we see, opened out by a great transverse fracture of the encircling ridges?

The same reasoning, I may add, is applicable to the grander denudation of the great valley of the Wealden of Kent, Sussex, and Surrey—a tract which I have explored for many years, and concerning the denudation of which I have formed opinions entirely differing from those of Lyell and Darwin. The former, exhibiting sketches of the escarpments of the North and South Downs, infers that they have been cliffs which were gradually eroded by waves of the sea. Adopting this view, Mr. Charles Darwin ('Origin of Species,' 1st edit., 1859, p. 287), logically estimates that the mere erosion of the sides of the Wealden Valley, according to the ordinary rate of wear-and-tear of wave-action, must have been a process lasting not less than three hundred million years!

Now I affirm that there is no proof whatever that the waves of the sea ever beat against or wore away the escarpments of either the North or South Downs; for if such had been the case, we should surely, somewhere in the great circuit of the chalk-cliffs which subtend the Wealden area for a distance of 160 miles, be able to detect some evidence of such shore-action, whether it took place during the latest Tertiary or at any subsequent periods. Gravel-beds formed by the action of breakers, whatever may be the date of their formation, are always clearly distinguishable by their rounded condition from all other kinds of drift translated by water. Such pebble-beds formed by waves of the sea are beautifully exhibited in the Tertiary strata at Woolwich and Blackheath, extending to Addington Heath, near Croydon; and pebbles similarly formed are seen in various raised beaches of more recent age around the coasts of Britain. In all these cases the pebbles are just like the shingle now rounded on the shore. But not a trace of such shore-action is to be detected at any level, at the foot or along the sides of the escarpments of the North and South Downs. In place of this, we there only find local heaps of angular and broken flints, the relics

the débris arising from the destruction of the different Silurian rocks within the ellipse, I made this observation —"When, however, we reflect upon the nature of the elevation, we see in it the inevitable result of the same powerful operations that have produced the form of the valley; for whether we embrace the hypothesis of a sudden [illegible] or of a number of shocks, we are compelled to call into play the action of currents, both violent and long continued, to explain satisfactorily the great extent of erosion; and when we see that excavation has proceeded so far as to groove the broad channels which surround the central dome and to carry away large portions of the associated (Silurian) rocks, why should we expect to find a trace of the wreck of the once overlying strata (Old Red Sandstone) which must have been removed before the work of denudation could commence upon the inferior deposits." ('Silurian System,' 1839, p. 436.)

of the Chalk which once covered the Wealden, and these chiefly upon the Greensands and Gault at small distances from the hills, and tumultuously aggregated—the residue, doubtless, of some of the enormous mounds of débris which must have resulted from the breaking-up and destruction of the Chalk which once covered over the whole area between the opposite escarpments of the North and South Downs *.

Further, if we look to the interior of this vast valley, we find the dome-shaped centre, consisting of the Weald Clay and Hastings Sand, just as entirely swept of any superficial fragment as in the smaller valley of Woolhope, except in those limited tracts of narrow dimensions where rivers of date long posterior to the great denudations have acted, and there left traces of their old beds, as in the case of the Medway, so well described by Messrs. Foster and Topley of the Geological Survey †.

By what ordinary currents of the sea, I ask, could such a sweeping-out be made over an area of nearly 200 square miles, throughout which, except where an ancient river-bed like that of the Medway, but flowing long after the great denudations, have left some shingle and gravel, every portion of the soil is but the decomposition of the denuded rock beneath?

I therefore believe that, during the several upheavals (for I am no believer in one such movement) which took place, by which the central dome was raised, the present valley was subjected to powerful and perhaps long-continued currents of water, purging the surface of all those vast mounds of débris which must have encumbered it after each upheaving dislocation of the central Wealden axis ‡.

Agreeing, as I do, with my associate Lyell in a belief in the constancy of laws of Nature, I am rejoiced to be his follower in reasoning from the present to the past: at the same time I maintain, from the evidences presented to me in the crust of the earth, that during former periods there were, at intervals, causes in action of much greater intensity than those of which the human race has ever had an example.

In speaking of the 'relative amount of work done by mechanical force in given quantities of time past and present,' Lyell adds §, "It is not the magnitude of the effects, however gigantic their proportions, which can inform us in the slightest degree whether the operation was gradual, insensible, or paroxysmal. It must be shown (he says) that a slow process could never in any series of ages give rise to the same results."

Now, to take one of the examples before cited, I affirm that by no pos-

* Doubtless the present softly rounded outlines of these beautiful Chalk hills are due to diurnal erosion by atmospheric agency during long ages, and some amount of unworn and frost-broken flints is due to this cause.

† Quart. Journ. Geol. Soc. vol. xxi. pp. 443 &c.

‡ I refer the reader, for further details on this point, to a memoir I wrote many years ago (see Quart. Journ. Geol. Soc. vol. vii. pp. 349 &c.), "On the Distribution of the Flint Drift of S. E. England &c." For proofs of the great force which operated in the upheaval of this grandest of our British valleys of elevation, accompanied as the movements necessarily were by rents and openings transverse to the main line of upheaval, see the admirable memoir of the late eminent mathematician, W. Hopkins, Trans. Geol. Soc. ser. 2. vol. vii. p. 1

§ Principles of Geology, 10th edit. vol. i. p. 136.

sible extension of gradual and insensible causes could huge masses of Tertiary rocks have been so thrown over as to pass under the older rocks of the Alps, out of which they were formed. That operation must have been paroxysmal, and no slow process could have accomplished it. The crust and outline of the earth are, in short, full of evidences that many of the ruptures and overthrows of the strata, as well as great denudations, could not even in millions of years have been produced by agencies like those of our times. Nor can I admit that we who appeal to the proofs of former intensity of causation are to be taxed with being 'prodigal of violence and parsimonious of time;' for we willingly allow any amount of time for the accretion in aqueous sediments of such matter as resulted from the diurnal wearing away of lands. We also readily admit, if valid proofs be given, that gradual uprisings and sinkings of lands have occurred in parts of the earth during the historic period; but, at the same time, we maintain that formerly acts of much greater violence in the dismemberment, and in denudation, of the strata took place than in any changes during our era.

Fully admitting that "deposition and denudation are processes inseparably connected"*, it is immaterial to my argument whether the destruction of vast masses of matter was both sudden and gradual or gradual only; for the amount of deposition would in all such cases balance the amount of abrasion; and whether the hills were ground down gradually or suddenly, the resulting detritus accumulated under water would be the same. If, indeed, it be rational to infer that, by the progressive thickening of the sedimentary crust, the internal heat being more and more repressed by each such addition, the surface has at length been fitted for the habitation of an intellectual being, are we not naturally led to believe that in historic times the earth's surface has been in a state of comparative repose, and subject to much more moderate undulations and depressions only, though here and there materially diversified by earthquakes and volcanic outbursts?

Again, I can see in existing nature no cause of sufficient intensity to account for ordinary sediments (once charged with organic remains) having been changed into crystalline masses occupying whole regions. The theorist in vain endeavours to explain such operation by processes so slow in their action as to be almost imperceptible. If it be argued that the strata constituting lofty mountains were metamorphosed in parts by such a slow process, let any one who sustains that view explain how it is that every stratum in a lofty range of mountains, composed of carbonate of lime, should in some cases all at once change into sulphate of lime, and in others into dolomite.

Whilst I state my objections to some of the tenets held by a large band of modern geologists, I am bound to say that I rejoice to witness the candour with which their eminent leader, Lyell, has recently written of deposits formed after what he terms "great revolutions in physical geo-

* See Lyell, 'Principles,' 10th edit. p. 107.

graphy" *. He alludes to "regions of convulsion, in which (in historic times) rocks have been rent asunder, the surface has been forced up into ridges, chasms have been opened out, or the ground throughout large spaces has been permanently lifted up above or let down beneath its former level." If such small results have been shown to man, why not admit that in former times the causation may have been more intense?

Further on, in the same instructive volume, we find that, in estimating the aggregate result of diurnal operations multiplied by time, he justly repudiates the idea of violent catastrophes and revolutions which affected the "whole earth and its inhabitants."

Not being one of those who ever held such an opinion, I have but to express my agreement with Sir Charles's present view, "that the more impressive efforts of subterranean power, such as the upheaval of mountain-chains, may have been due to multiplied convulsions of moderate intensity, rather than to a few paroxysmal explosions" †. I only beg to reassert the belief I have long entertained from evidences before me, that those 'convulsions' were infinitely more powerful than any one of which history records an example. I infer, indeed, that each of those upheavals or depressions which gave rise to terraces of marine shells at separate heights upon our lands or to submerged lines of coast must have displaced large volumes of water possessing great denuding power. On the contrary, if the bottoms of seas had always been gradually raised, or the lands equably and slowly depressed (as is said to be now the case in Scandinavia), the currents of the ocean at such times could never have acted with force sufficient to denude the adjacent lands; for it is well known, I repeat, that deep seas never sweep away broken materials, and only accumulate fine silt or minute organic bodies.

Before I quit this branch of the general subject of geology, which treats of the physical agencies which have brought the earth's crust into its present outline, I must further be permitted to express my dissent from those who would account for the production of all valleys and gorges by the action of the water that has flowed in them. I fully admit that, in mountainous regions, rivers, whether flowing or in the form of glaciers, have abraded and deepened their channels. I further admit that in volcanic regions rivers descending from considerable heights into plains have

* See 'Principles of Geology,' edit. 1866, vol. i. pp. 120, 310, 318.

† In a sketch of the life and writings of my lamented friend the late Dr. Whewell, Master of Trinity College, Cambridge, I used these words:—"In speaking of Uniformitarians, as Whewell defined those geologists to be whose leader is my eminent friend Lyell, the worthy inheritor of the mantle of Hutton and Playfair, let it not be supposed that any reasonable geologist, certainly not myself, who may dwell upon the great and sudden dislocations which he believes the crust of the earth underwent from time to time in far bygone periods, is not also a strenuous advocate of an uniformity of causation as respects the enormously long and undisturbed periods required to account for the accumulation of the thick sedimentary deposits. On the other hand, unbiased Uniformitarians now admit of occasional catastrophic action; and, as the question is thus reduced to be one of degree only—that degree to be fairly gauged by measuring the relations and extent of the ruptures of the crust of the earth—I feel confident that out of fair discussion the exact truth will ultimately be obtained."—Address at the Anniversary Meeting of the Royal Geographical Society, May 1866. Trans. Roy. Geograph. Soc vol. xxxvi. p. cxxiv.

reexcavated valleys which at no very remote period were filled with coulées of basalt. This phenomenon, so strikingly brought before English geologists forty-two years ago by the pen and pencil of Mr. G. Poulett Scrope, was abundantly verified by Sir Charles Lyell and myself when we explored Auvergne together in 1828.

On the other hand, I maintain that the clearest proofs abound that in numberless cases rivers have simply availed themselves of the courses prepared for them by previous breaks in the rocks, opening depressions along which the waters have passed. Take one of the largest of our European streams, the Danube, and trace it from its source in the flat plateaux of Central Germany, in which it rises, and you see that, whilst it never can have been a torrential stream, it simply maintains a steady slow-flowing current as it winds through the steep defiles and high cliffs of the hardest gneiss and granite, which had been opened out to receive it; for, even now, where the gorges are the deepest and narrowest, and where the river must therefore have exerted its greatest power, the buildings of Roman times have been daily bathed by the stream, and not a fragment of them has been worn away.

Then, if we turn to Britain, no one who has examined the tract of Coalbrook Dale will contend that the deep gorge in which the Severn flows at that place has been eaten out by the agency of the river (there so powerless), the more so when that great fissure in the Silurian rocks is at once accounted for by their abrupt severance, with an entire unconformity between the strata of Wenlock limestone occupying the opposite sides of the valley. Now in that part of Shropshire the Severn has not worn away the slightest portion of the rocks during the historic era, nor has it scooped out a deeper channel: it has only deposited silt and mud, and increased the extent of land upon its banks.

The valley of the Avon at Bath, for example, is also the seat of one of those disturbances to which Sir Charles Lyell alluded when he candidly said that he had "little doubt that the Bath springs, like most other thermal waters, mark the site of some great convulsion and fracture which took place in the crust of the earth at some former period" *,—the hot waters of that city having ever flowed out of a deep-seated fissure, clearly marked by the strata on the one side of the valley having been upheaved to a height 200 feet above that which they once occupied in connexion with those of the other side. When, indeed, we look to the lazy-flowing, mud-collecting Avon, which at Bath passes along that line of valley, how clearly do we see that it never deepened its channel! still more when we follow it to Bristol, and observe it passing through the steep gorge of hard Mountain-limestone at Clifton, every one must then be convinced that it never could have produced such an excavation. In fact, we know that, from the earliest periods of history, it has only accumulated mud, and

* Report of British Association, 1864: Address, p. lxiv.

has never worn away any portion of the rock. The clear inference, then, in these and countless other instances is that rivers in all such cases simply flow in the gorges and depressions prepared for them by previous geological disturbances.

There is yet another subject of discussion in the physics of geology on which I must express my dissent from the views of some of my most esteemed associates, whose other works I highly admire. In a preceding page I have expressed my belief that, in the earlier or Palæozoic times, the lands never rose into very lofty mountains, nor were the sea-bottoms so deep as in the present day. Had the present diversified outline of the earth, or even an approach to it, existed in the Palæozoic era, most assuredly the same groups of animals and plants could not have been spread as they were over such enormous areas as those over which we find their remains; for the deep sea is to all 'Laminarian' marine creatures as impassable an obstacle as the high mountains are to the spread of land animals.

Again, if very lofty mountains had existed in Palæozoic times, we should somewhere find distinct proofs that snow and glaciers then prevailed; but of this phenomenon I cannot admit that valid proofs have yet been given. The discovery by Professor Ramsay of some smoothed and striated stones at one place among the Permian rocks of England cannot, I think, be held as a proof of true glacier-action *, seeing that there are other agencies by which such scratches may have been produced. We must recollect that the Permian period was one of igneous activity and great disturbance; and in such a state of nature we can very well imagine how, by the friction of rock-masses against each other (as in one of the elevations of the adjacent Malvern Hills), such striæ might have been produced. Still less can I admit that the blocks in the much older conglomerate of the Old Red Sandstone of Scotland were transported by ice; for all these are purely local conglomerates, piled up against, or lying upon, the older rocks out of which they have been compounded. They are therefore, in my opinion, simply the results of some of the powerful earthquakes, dislocations, and debacles which, as I contend, have affected the earlier crusts of the earth, and thus left them as detrital materials almost *in situ*.

Imbued with this belief, I must also demur to the opinion which might be derived from an inspection of the sections of my distinguished friend Professor Ramsay, when he carries up to extreme heights those dotted theoretical lines over his actual and truthful sections, by which he indicates the probable altitude of mountains in ancient geological times, by supposing the upward continuation of strata which have really been truncated near the surface of the earth. If the highly inclined lines of strata on the opposite sides of a broad dome of older rock really continued in an

* Compare Professor Ramsay's Memoir on the subject, Quart. Journ. Geol. Soc. vol. xi. pp. 185 &c.

unbroken curve, the upheaved Palæozoic rocks must occasionally have constituted mountains as high as any existing snowy mountains of the present period *. Such a view of our subject cannot, it seems to me, for many powerful reasons, be sustained. Thus the plants and animals which lived in the subsequent Devonian and Carboniferous periods all clearly indicate that those deposits were formed under a warm temperature, and were not accumulated in cold climates.

Again, if we are to believe in the existence of such lofty mountains in the oldest periods, we must suppose that a warm climate prevailed in the low countries and that glaciers existed only at great heights; and if so, how can we rationally explain the entire destruction and disappearance of such gigantic masses of solid matter as must have taken place over such vast areas? On the other hand, if we restrict our conception of such dislocations and upheavals to their having simply affected those portions of the strata which, anterior to their rupture, were more or less horizontal, and that they never were raised into the lofty domes hypothetically assigned to them, we can then readily believe how inundations and other agencies through long ages, may have swept away such restricted accumulations of broken materials.

Before I quit the consideration of those former proofs of a greater intensity of former causation, I may well rejoice in knowing that my opinions as a practical geologist, and derived solely from facts, have been supported by that eminent mathematician Sir William Thomson, entirely on the principles of thermo-dynamics, which, as he says, have been overlooked by those geologists who uncompromisingly oppose all paroxysmal hypotheses. In a memoir on the "Secular Cooling of the Earth" †, he has shown that "the solar system cannot have gone on, even as at present, for a few hundred thousand or a few million years without the irrevocable loss (by dissipation, not by annihilation) of a very considerable proportion of the entire energy initially in store for sun-heat and for plutonic action. In another memoir ‡ he has shown that probably the sun has been sensibly hotter than now: "Hence (he observes) geological speculations assuming somewhat greater extremes of heat, more violent storms and floods, more luxuriant vegetation (*ex. gr.* the Coal-period) are more probable than those of the quietest or Uniformitarian school." After showing the secular amount of loss of heat from the whole earth, and repudiating the chemical hypothesis that the substances combining together may be again separated electrolytically by thermo-electric currents due to the heat generated by their combination, and thus the chemical action and its heat continued in an endless cycle,—this, he says, "violates the principles of natural philo-

* See for instance the Mem. of Geol. Survey, vol. i. pp. 297 &c. plates 4 & 5, and vol. iii. pl. 29. If the ingenious views of my distinguished friend be explained by calling in enormous dislocations and denudations, these certainly would be plain evidence of the greater intensity of causation in former periods.

† Trans. Roy. Soc. Edinburgh, vol. xxiii. pt. 1, and Phil. Mag. ser. 4. vol. xxv. pp 1 &c.

‡ Macmillan's Magazine, March 1862.

sophy in exactly the same manner, and to the same degree, as the belief that a clock constructed with a self-winding movement may fulfil the expectations of its ingenious inventor by going for ever. It must be admitted," he adds, "that many geological writers of the Uniformitarian school, who in other respects have taken a profoundly philosophical view of the subject, have argued in a most fallacious manner against hypotheses of violent action in past ages." And then, in support of his own views, he asks these pertinent questions: "Is not this, on the whole, in harmony with geological evidence, rightly interpreted? Do not the vast masses of basalt, the general appearance of mountain-ranges, the violent distortions and fractures of strata, the great prevalence of metamorphic action (which must have taken place at depths of not many miles, if so much), all agree in demonstrating that the rate of increase of temperature downwards must have been much more rapid, and in rendering it probable that volcanic agency, earthquake-shocks, and every kind of so-called plutonic action have been, on the whole, more abundantly and violently operative in geological antiquity than in the present age?"*

Seeing that the view I long ago adopted solely from an appeal to geological phenomena has since been supported on these independent grounds by the reasoning of one of our leaders in physical science, I return to the consideration of the main object of this work, or the History of the Palæozoic Ages—a subject happily on which all geologists are, I trust, now agreed.

If we reflect upon the succession presented to us in the primeval deposits, we have, I repeat, cumulative evidence to prove that the wide-spread diffusion of the same types of animal and vegetable life was due to a former temperature and outline of the surface essentially different from those of our day. To whatever extent continents and islands may have existed during those long early periods, and however we may speculate on the extent of pristine shores, it seems certain that the lands accessible to our research increased in size very considerably at the close of the Devonian period, and especially in the Carboniferous times. In those days the very same species of marine animals lived from the latitude of Spitzbergen to the parallels of Peru and Australia†. Then also vast low deltas stretched out in every direction, bearing a uniform terrestrial vegetation, absolutely identical over at least half the globe. Many of the ancient Tree-ferns must have grown on tracts little above the water: and jungles larger than Britain must have been successively and repeatedly submerged and renewed, forming lands loaded in time with the accumulated vegetation

* Phil. Mag. ser. 4. vol. xxv. p. 9.

† The Peruvian Andes, and other parts of the Cordillera ranging into California, have afforded several species of Carboniferous Mollusca identical with British forms, and I have myself found the same in the Ural Mountains: see 'Russia-in-Europe and the Ural Mountains,' vol. i. p. 73. They also occur in Australia: see M'Coy, Ann. Nat. Hist. 1847. For the numerous forms of Carboniferous types in Spitzbergen see Quart. Journ. Geol. Soc. vol. xvi. pp. 439 &c., and the results of the late Swedish Expedition, Trans. Acad. Stockholm, 1866.

that supplied the elements for the construction of great coal-fields. (See Sketch, p. 286.) These phenomena assure us, therefore, that a very great portion, if not indeed the whole surface of the earth, enjoyed at that time an equable and warmer climate.

Believing, as I do, with some geologists, that this former temperature of the earth was, in a measure, probably increased by the radiation of its internal heat, independently of solar action, other physical as well as zoological phenomena lead me further to suppose that the land of those early days could not have been thrown up into lofty mountains; for, if so, such great elevations must have been accompanied by corresponding deep chasms in the crust of the earth, and these would necessarily have been impassable barriers to the groups of marine creatures which have been described as more or less coexistent over wider regions *. Profound abysses of the ocean are, it is well known, as complete barriers to the migration of Fishes and many other marine creatures, as lofty mountains are to inhabitants of the land. The discovery, therefore, of the vast profundity of the ocean midway between the Cape of Good Hope and Cape Horn, amounting (it is said, even allowing for some amount of error in the soundings) to 7000 fathoms, or nearly double the height of the loftiest mountains, is, indeed, the strongest possible illustration of the impassable nature of such subaqueous barriers. These existing hollows have resulted from many great oscillations of the surface, in comparatively recent geological periods, which have caused great variations in the 'marine provinces' of existing animals, and placed them in strong contrast with the uniformity of the ancient wide-spread faunas.

Duly estimating the great value of the knowledge of marine life acquired and applied by a naturalist whose researches, coupled with those of Lovén and other cotemporaries, have thrown new light on many phenomena previously unexplained, let us guard against the inference that, because such acquaintance with the natural operations of our own era is applicable to the last geological data, or those of Tertiary age, it should also apply to the quasi-universal, and therefore very different, physical conditions under which primeval creatures existed. During the Tertiary period, the crust of the earth had, as we know, approximated considerably to its present varied outline; and before it drew to a close, great changes had taken place, by which regions formerly occupied by animals and plants requiring a warm and equable climate were covered even by ice and glaciers. Whilst, therefore, we thank Edward Forbes for dredging the sea-bottoms, and teaching us that deep-sea mollusks are now living near high lands in the Mediterranean, whence pebbles may be so washed down as to lie in juxtaposition with the tenants of the deep, we must believe that either this argument cannot bear upon the primeval era, in which we have

* Cuvier and Valenciennes showed (Hist. Poiss.) that very few species of Fish cross the Atlantic, and the Reports to the British Association by Sir J. Richardson (1836, 1845) lead us to infer that deep seas are as impassable barriers to Fishes as high mountains are to Mammals.

no evidence whatever of high lands and detached mediterranean seas, or, if applied, it is the strongest evidence to show that the supposed primeval cliffs and lands were void of terrestrial vegetation.

On what data, it may be asked, is founded the beautiful and rational theory of Lyell, which explains the successive changes of the climate of the earth? Is it not mainly dependent on those diversified evolutions, proceeding from beneath the surface, which have caused changes in the outline of former lands and seas, equivalent in extent, although different in position, to our present continents and oceans? And if such a varied distribution of earth and water as the present had existed in the pristine periods that we have been considering, how could the same groups of animals, manifestly requiring the same conditions, the same temperature, and the same food have had so wide a diffusion?

Although it is quite true that specific distinctions are seen to have frequently prevailed in the fossils of the Lower Silurian rocks of countries situated at no great distance from each other, as explained in the Chapters which treat of the distribution of the fauna of that age, the fact is by no means antagonistic to my reasoning. Should it, for example, be even said that the variety in the distribution of Silurian species is as great as in the same areas of sea of the present day, I reply that it is not to species, but to the classes, families, and genera that, as a matter of fact, I appeal. If so many Trilobites, Cephalopods, Brachiopods, Cystideans, and Corals of analogous forms were spread out over areas at enormous distances, in the earlier primeval times, proving that oceans containing similar groups extended from China and the Himalayan Mountains, over Siberia and Russia to Western Europe, it is enough for me to feel assured that the various associates of the Calymene Blumenbachii, or any well-known Trilobite, must have required just the same temperature and surrounding media in whatever part of the world they lived. It is not because the land animals of Europe are dissimilar in *species* to those of Africa that the faunas of the two regions are so distinct, but because we have not among our European associates the same *groups* as those which live in hotter climes. I therefore conceive that the fact of the wide diffusion of the same families and genera of Trilobites, Corals, and other fossils, however they may vary as to species, must have required an equably diffused temperature and similar conditions for their existence. Still more clearly is this inference sustained in the Carboniferous era by the spread of the same old vegetation, and often of the same species of Plants over half the globe.

Having thus written in the last edition of this work, I am now, indeed, enabled to speak more conclusively on this point and to the same effect, thanks to the labours of Dr. Bigsby. The geologist who seeks to acquire a thorough acquaintance with the very wide diffusion of the whole Silurian Fauna must consult the forthcoming 'Thesaurus Siluricus' of that indefatigable author, the result of many years of labour and research in both

hemispheres. Assisted by Mr. Salter and Mr. Etheridge, he has registered no less than 7553 well-defined species of fossils that lived during the Silurian epoch, thereby showing that in the last ten years the number of known species has been more than trebled. When, indeed, we consider that through the enlightened researches of Barrande, a small tract around Prague has already yielded a third of the hitherto recognized Silurian remains, we may well imagine what will be the number of the fossil population of that age to be cited by the geological statists of the next century. A glance at the Tables of the 'Thesaurus Siluricus' will show the groups of fossils which are common to the most distant centres; and we thus ascertain that some of the *species* even are common to Britain, Scandinavia, Bohemia, America, and the Antipodes in Australia. These data prove that the Silurian system of life had an almost universal spread; for the knowledge we have obtained has been gathered, as the work well reminds us, from widely separated spots only on the surface of the earth, the greater mass of such old rocks being hidden beneath the younger formations. Another remarkable result of the researches of this geologist is the amount of the frequent recurrence of species in the range of Silurian life. Thus, in pursuing the method of analysis and comparison first applied by Professor John Phillips to the Carboniferous era, Bigsby enumerates no less than 803 species (or 12 per cent. of the whole number) which have maintained their existence during vastly long periods, though after all 6200 species out of 7553 are severally restricted to one horizon. Equally striking is the generalization given in this 'Thesaurus' regarding the geographical distribution of Silurian life, particularly as exhibited in the grand natural features of British North America, where the formations of that period extend over an enormous area, as well shown in the map of Canada and neighbouring States by Logan and his associates, referred to in Chapter XVIII.

Resting then on these universal facts as a firm basis, the geologist who explores his way upwards sees, as before stated, that the formations which were next accumulated in the same latitudes as the Silurian rocks, and sometimes in actual and conformable contact with them, do contain Land Plants mixed with marine remains. In short, the only prevailing unequivocal vegetables found in the oldest strata are Sea-weeds; whilst the after-formed and contiguous rocks, though equally charged with exuviæ of the sea, are laden with many spoils of the land, both vegetable and animal.

Patient researches having thus demonstrated that in the primeval eras all living things differed from those of our own times, we also see how the animals subsequently created were adapted to new and altered physical conditions. Proceeding onwards from the early period in which we can trace no sign of Trees on the land, or of Fishes in the sea, and in which the solid materials, enclosing everywhere a similar fauna, were widely spread out with great uniformity, we soon begin to perceive that,

with the augmentation of dry lands and the growth of trees, as seen in the Devonian system, Fishes abounded, to be followed afterwards by Reptiles. Subsequent to the accumulation of the Carboniferous rocks, we have proofs that the earth's surface was so powerfully corrugated* that, after many Mesozoic perturbations, the groups of animals and plants of the Tertiary periods were far more restricted to limited regions and varied climates.

On the other hand, the numerous and positive evidences of a former wide distribution of similar animals and plants enable us fairly to bring before our mind's eye the physical geography of those long epochs when such large portions of our present continents were under the waters, and jungles of succulent and fern-like trees occupied extensive low lands, subjected during long periods to sinkings and uprisings, both gradual and sudden. Not less clearly do we perceive, from other physical evidences, the manner in which eruptive forces subsequently breaking out with violence after the close of the Carboniferous era, as at many other periods, have thrown the strata into those grand undulations and contortions, accompanied by stupendous fractures, which have given to the Palæozoic, and even the Secondary deposits their curvatures and limits.

Thenceforward was continued that long series of additional and repeated emissions of volcanic matter from within, of elevations of sea-bottoms and corresponding depressions of land, combined with the metamorphism of strata (these changes being often accompanied by corresponding new creations of animals suited to the existing conditions), during the formation of the Secondary and Tertiary deposits. By these great physical operations, both gradual and paroxysmal (some of the grandest of which must have occurred in recent geological times), our planet was eventually brought to possess the climatal relations which have for so long prevailed. That these elevations and depressions finally produced a state of things very different from that of such former eras, is, indeed, everywhere registered by a multitude of well-attested data.

Among the terrestrial changes to which science clearly points, there is no one which better deserves to be alluded to in a few parting words, than that great mutation of climate, by which extensive fields of ice were first, as I believe, formed upon the sea, and large glaciers upon the land. As very lofty mountains in moderate latitudes, and masses of land and water in Arctic or Antarctic regions, are essentially the seats of glaciers and ice-rafts, so we know that these bodies alone have the power of transporting huge erratic fragments of rocks from their native mountains to

* I by no means deny that much perturbation prevailed in the earlier stages of the planet, as explained in the first two Chapters. On the contrary, I admit the powerful emission of much igneous matter, the transmutation of sedimentary into crystalline rocks, and the emergence of great land-areas, anterior to the accumulation of any of the deposits which are now under consideration; but I deny that there are indications of the existence of any lofty mountains until the crust of the earth had undergone some of the subsequent mutations alluded to, particularly those which followed the accumulation of the Carboniferous strata, and which were repeated at so many subsequent periods, notably, and perhaps most powerfully, in the Tertiary times which preceded the historic era.

considerable distances by land, or for hundreds of miles over the sea in floating icebergs. Now, of the far removal of such gigantic blocks we have no clear evidence in any preceding geological period! On the contrary, whilst most large boulders of the Primary, Secondary, or older Tertiary rocks bear on their surfaces the signs of having been water-worn or rounded by aqueous or atmospheric agency, and have been transported to comparatively short distances from their parent rocks (like the conglomerates of the Old Red Sandstone of Scotland), the huge erratics of the later cold period (gigantic in comparison with all that preceded them) are often angular, or nearly in that state in which they left the mountain-side—before, in short, they were wafted over seas or lakes, to be dropped, hundreds of miles from their parent rocks, upon submarine sediments, which by subsequent elevation have been made portions of our continents. Hence, independently of the indications of a more equably diffused and warmer temperature in older times than at the present day, such large erratics are in themselves decisive testimonials of that intense cold which, it is believed, was principally due to the increase of great elevated masses of land specially characteristic of the *quasi*-modern period *.

Receding backwards from this glacial phenomenon †, which, continuing into our own times, has been so skilfully illustrated by eloquent writers, it is specially my province to impress upon the reader the importance of endeavouring to form an estimate of the physical geography of the earth during those remote periods when the Palæozoic deposits were accumulated. If, as I firmly believe, lofty mountains did not then exist, we have, indeed, in this single condition what may have been one of the chief causes of that equable, if not warmer, climate the presence of which seems an indispensable hypothesis to harmonize the facts recorded in this volume: and if we add the inference adopted by many philosophers and geologists, that the earth, in cooling down from its original molten state, must, during immensely long succeeding ages, have gradually lost its heat over the whole surface, we are enabled, by reference to physical changes alone, to satisfy ourselves that we have in them the chief elements required to explain many climatal results.

Finally, although this rapid survey of the changes of the earth is but the outline of a picture which must be filled up by an assiduous study of the works of nature during ages yet to come, let me say that it has not been attempted without deliberate consideration and extensive researches, du-

* As I do not believe that the blocks in the Old Red Conglomerates of Scotland were transported by ice, so I am not called upon to enter into the ingenious cosmical and astronomical theory of Mr. Croll, which would account for the existence of Palæozoic glaciers. See Appendix S.

† In mentioning the Glacial Period, I embrace in one long epoch the formation of vast glaciers over large parts of the then snow-covered regions of the earth, as well as the melting of the same, when their débris, including huge icebergs and erratic blocks, were transported to enormous distances, often striating the rocks on which they impinged before they were finally deposited on the old sea-bottoms. Some authors of distinction, however, view these physical operations as indicative of two distinct glacial periods, separated from each other by a much warmer period, in which forest trees and large quadrupeds flourished; and it has even been inferred that Man existed before the last of these icy epochs. The reader will find this latter view (to which I do not yet assent) eloquently and attractively described by Professor Charles Martins, of Montpellier, in the 'Revue des deux Mondes,' 1867.

ring a long life, amid the youngest as well as the most ancient deposits; and if the theoretical considerations in the few preceding pages be objected to, they can easily be separated from those historical facts which are established by positive observation, and in the truth of which all geologists are agreed.

The leading object of this volume, I therefore repeat, is to call attention to the earliest vestiges of life which have been discovered in the crust of the globe, and accurately to chronicle the order in which other and more highly organized races followed them.

From the effects produced upon my own mind through the study of these imperishable records, I hope my readers will adhere to the views which I entertain of the succession of life from lower to higher classes, always bearing in mind that the first living animal of each class was as perfect and composite in structure as any of its congeners in after-times. I therefore cannot but believe that he who, looking to the earliest visible signs of life, traces thenceforward a rise in the scale of beings until Man appeared upon the earth, must acknowledge in these successive works continuous manifestations of the Design of a CREATOR.

P.S. The last published volume illustrative of the palæontological researches of M. Barrande * has been transmitted to me by the author whilst these pages are going through the press; and in it I find the clearest elaboration of the proofs that (like the primeval Crustaceans, the Trilobites) the Cephalopods (of the Nautilide family) attained by far their greatest development in the Silurian period, their numbers lessening by a very rapid decrement in each of the succeeding great Palæozoic formations. Now this datum, the result of long labour and perspicuous discrimination, is strikingly confirmatory of my established geological postulate, that, with the exception of its youngest member, the Silurian system was an 'Invertebrate Period' of immensely long duration. I have suggested (p. 485) that the natural function of Fishes as destroyers of the lower marine animals was exercised in Silurian times by numerous Cephalopods; and it gratifies me to find that the numbers of the latter in those early days infinitely exceeded that of which we have hitherto had any knowledge. Again, the same view of very long Invertebrate Periods has been sustained by the authority of Professor Dana, who has termed the Silurian era the "Age of Mollusks" †.

* 'Système Silurien du Centre de la Bohême,' Partie I. 'Recherches paléontologiques,' vol. ii Céphalopodes (Texte), 4to, 1867.

† 'Manual of Geology,' 1863, p. 128.

APPENDIX.

A.—*Table showing the Vertical range of the Silurian Fossils of Britain.*

In the Appendix to the First Edition of this work, the range of those species only which are common to the great divisions Upper and Lower Silurian was exhibited in a tabular form. I am now enabled to give a complete list, so far as our present knowledge extends, of all the species, and to particularize their occurrence in the Subdivisions of the System—thus following the plan adopted in the original 'Silurian System.'

Mr. J. W. Salter, aided by Prof. Morris, in the year 1859 compiled the Table published in the last edition. In the reconstruction of the Table for the present volume nearly 300 new forms have been incorporated with the previously known Silurian Fauna. Several published species are omitted, because a careful examination has shown their identity with others previously described. The list now comprises all the hitherto well known British Silurian fossils, and shows their range throughout the different subdivisions.

It is to be understood that Mr. Salter, who prepared the last edition of this Table, is not responsible for any inaccuracies it may contain in its present form. The additions and emendations have been chiefly made by Mr. Etheridge, assisted by Prof. Morris and Prof. Jones. The student will observe that many of the long-known names of Silurian fossils have been exchanged for more correct names according to the recent determinations of their real alliances, often obscure before, and only established on the discovery of more perfect specimens, and by an extended knowledge of extinct forms of life. To the palæontological labours of Mr. Salter and Mr. Davidson we owe many of the more exact recognitions that have lately been made of the relationships of various Trilobites, Mollusks, and other fossils, as well as many descriptions of newly discovered forms. See especially Davidson's 'Monograph on the Silurian Brachiopods,' and Mr. Salter's 'Monograph of the British Trilobites,' 'Appendix to Ramsay's Geology of North Wales,' &c. Mr. Davidson has examined the list of published Brachiopods, and Dr. Duncan that of the Corals; Mr. Carruthers has revised the Graptolites, and Mr. Henry Woodward the Eurypteridæ; and the improved nomenclature advanced by these and other palæontologists has been adopted in the body of the work. In the Explanations of the Plates, also, many of the old names will be found to have been exchanged for others more correct as to generic and specific affinities, or entitled to use by priority.

The Lingula-flags (M. Barrande's 'Zone Primordiale' of the Silurian rocks, 'Primordial Silurian' of the Table) have, as explained in the body of this work, their fullest development near Tremadoc, Barmouth, and Dolgelly, in North Wales, and in St. Bride's Bay, south of St. David's, on the west coast of Pembroke in South Wales. In the Silurian tract of Shropshire they are, in my opinion, represented by the dark schists which underlie the Stiper Stones, and are superposed to the greatest mass of the Cambrian strata known in England and Wales, namely, the Longmynd.

The Llandeilo Group of rocks, comprising the Lower Llandeilo (or Tremadoc) Slates, and the Llandeilo Flags proper, are black, flag-like, and slaty deposits, occasionally calcareous, extensively developed at Tremadoc and Ffestiniog in North Wales, also in Shropshire, and in South Wales at Llandeilo, Builth, &c. They include at their base the dark-grey flagstones and schists which occupy the western slopes of the Stiper Stones (see pp. 47 &c.). The fossils of these two groups are included in the column headed 'Llandeilo.'

In the 'Caradoc' column are included all the rocks of the Caradoc sections of Shropshire, the Bala Limestone, and the arenaceous beds above and below it, all which beds overlie the black slaty Llandeilo series in North and South Wales (see pp. 63 &c.). The fossils of Snowdon, of Coniston in Westmoreland, of Ayrshire, Tyrone, Dublin, Waterford, Wexford, &c., are also included in this division.

The fossils of the Lower and Upper Llandovery rocks are included in one column ('Llandovery'), because they constitute an intermediate group; but the reader will see in the text that I have clearly indicated their distinction, showing that the Lower Llandovery rocks unite naturally with the Lower Silurian, and the Upper Llandovery with the Upper Silurian. (See also the Legend at the side of the Map.)

The Woolhope Limestone and the Denbighshire Grits are here regarded as the lowest portion of the Wenlock rocks; and the 'Coniston Grits' of Professor Sedgwick with their few fossils are included in the same group. The fossils of the Bog-mine, near Shelve, Shropshire, are also thus placed, as they are Upper-Silurian species.

The 'Ludlow' column embraces the Lower and Upper Ludlow rocks and the intervening Aymestry Limestone; whilst the term 'Passage-beds' refers to that thin band ('Ledbury Shales' of Salter) which exhibits a passage from the Upper Ludlow to the Old Red Sandstone,—the Downton Castle Sandstone being retained with the Ludlow rock proper (pp 135 &c.).

[In the following List, references are made to the Woodcuts of Fossils in the text, and to the Plates at the end of the work, in a distinct and darker type.]

PLANTÆ †.	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ACTINOPHYLLUM plicatum, Phil. M. G. S. ii. p. 386						*	
CHONDRITES verisimilis, Salt. M. G. S. Expl. Sheet 32. pl. 2. f. 1, 2					*		
FUCOIDES. **Foss. 16. p. 96**				*			
PACHYTHECA sphærica, Hooker. **Pl. 35.** f. 30						*	*
SPONGARIUM æquistriatum, M'Coy, Pal. Fos. p. 42						*	
Edwardsi, Murch. **Pl. 12.** f. 3						*	
interlineatum, M'Coy, Pal. Fos. p. 43						*	
interruptum, M'Coy, Pal. Fos. p. 43						*	

† The nature of some of the fossils under this head is doubtful.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
SUBKINGDOM PROTOZOA.							
Class AMORPHOZOA.							
ACANTHOSPONGIA Siluriensis, M'Coy, Sil. Fos. p. 67			*				
AMPHISPONGIA oblonga, Salter, M. G. S. Explan. Sheet 32. pl. 2. f. 3						*	
CLIONA (Vioa) antiqua, Portl. Geol. Rep. p. 360			*				
prisca, M'Coy, Pal. Fos. pl. 1 B. f. 1				*		*	
CNEMIDIUM tenue, Lons. **Pl. 38.** f. 11					*		
FAVOSPONGIA Ruthveni, Salt. MS (Pal. Fos. pl. 1 D. f 9)						*	
INTRICARIA obscura, Portl. Geol. Rep. p. 326			*				
ISCHADITES antiquus, Salt. M. G. S. iii. p. 282. f. 4		*					
Kœnigii, Murch. **Pl. 12.** f. 4		*			*	*	
tessellatus, Salter, MS.			*				
? NIDULITES favus, Salt. **Foss. 30.** f. 3				*			
PROTOSPONGIA diffusa, Salt. Brit. Assoc. Rep. 1865, p. 285	*						
fenestrata, Salt. Q. J. G. Soc. xx p. 238, pl. 13. f. 12	*						
SPHÆROSPONGIA hospitalis, Salt. Trans. Woolhope Nat Club, No. 4, p. 25			*				
? STROMATOPORA striatella, d'Orb. (S. concentrica, Sil. Syst.) **Foss. 52; Pl. 41.** f. 31			*	*	*		
? TETRAGONIS Danbyi, M'Coy, Pal. Fos. pl. 1 D. f. 7, 8						*	
? VERTICILLIPORA abnormis, Lons. **Pl. 38.** f. 10					*		
SUBKINGDOM CŒLENTERATA†							
(ZOOPHYTA).							
Class ACTINOZOA.							
ACERVULARIA luxurians, Eich. **Foss. 54.** f. 6; **Pl. 39.** f. 6. (Astræa ananas, Sil. Syst.)					*		
ALVEOLITES Grayi, Edw. Brit. Cor. p. 262					*		
Labechei, Edw. (Favosites spongites, Lons.) **Foss. 18.** f. 5, **Pl. 40.** f. 8			*?	*	*		
repens, Lons. Sil Syst. p 680, pl. 15. f. 30			*		*		
? seriatoporoides, Edw. Br. Cor. p. 263					*		
AULACOPHYLLUM mitratum, His. Leth. Suec. p. 100					*		
CLISIOPHYLLUM vortex, M'Coy, Pal. Fos. p. 33, pl 1 B f 18					*		
CHONOPHYLLUM perfoliatum, Edw. Brit. Cor. p. 291					*		
CŒNITES intertextus, Eichw. (Limaria fruticosa, Lons.) **Pl. 38.** f. 8				*	*		
juniperinus, Eichw. **Foss. 20.** f. 3. (Limaria clathrata, Lons.) **Pl. 38.** f. 7					*		
labrosus, Edw. Brit. Cor. p. 277					*		
linearis, Edw. Brit. Cor. p 277					*		
strigatus, M'Coy. Pal. Fos. p 22					*		
CYATHAXONIA Siluriensis, M'Coy, Pal. Fos. p. 36						*	
CYATHOPHYLLUM angustum, Lons. **Pl. 39.** f. 9				*			
articulatum, Wahl. (cæspitosum, Lons. *non* Goldf., Cladocora sulcata, Lons ?, and Strephodes Craigensis, M'Coy, Pal. Fos. pl. 1 C. f. 10.) **Foss. 54.** f. 1; **Pl. 38.** f. 9; **Pl. 39.** f. 10			*	*	*		

† Under this head Graptolites are arranged by some as HYDROZOA; but they are placed provisionally with the Polyzoa at p. 522.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
CYATHOPHYLLUM flexuosum, Lons. **Pl. 39.** f. 7					*		
Loveni, Edw. Brit. Foss. Cor. p. 280					*		
pseudo-ceratites (Strephodes), M'Coy, Pal. Fos. p. 30					*		
trochiforme, M'Coy, Brit. Pal. Fos. pl. 1 B. f. 21					*		
truncatum, Linn. (C. dianthus, Lons., Strephodes vermiculoides, M'Coy, Pal. Fos. pl. 1 B. f. 22.) **Foss. 54.** f. 2 & 3; **Pl. 39.** f. 12, 12 *a–e*					*		
CYSTIPHYLLUM cylindricum, Lons. **Foss. 54.** f. 8; **Pl. 38.** f. 3				*	*		
Grayi, Edw. Brit. Cor. p. 297					*		
Siluriense, Lons. **Foss. 54.** f. 7; **Pl. 38.** f. 1					*		
FAVOSITES asper, d'Orb. (alveolaris, Lonsd.). **Foss. 18.** f. 4; **Pl. 40.** f. 1, 2 (?)			*	*	*	*	
crassus, M'Coy. Edw. Brit. Cor. p. 261			*				
cristatus, Blum. (F. polymorpha. Sil. Syst.). **Foss. 18.** f. 1; **Pl. 41.** f. 2				*	*	*	
fibrosus, Goldf. (Stenopora, Brit. Sil. Cor. pl. 61. f. 5). **Foss. 18.** f. 7; **28.** f. 1, 2; **Pl. 40.** f. 6, 7, var. incrustans, M'Coy, **Foss. 18.** f. 8; **Pl. 41.** f. 1.—Alveolites fibrosa, Lons., var. lycoperdon, Hall. **Foss. 31.** f. 2			*	*	*	*	
Forbesii, M.-Edw. Brit. Sil. Cor. pl. 60. f. 2					*	*	
Gotlandicus, Linn. **Foss. 18.** f. 2, 3; **27.** f. 6; **Pl. 40.** f. 3, 4			*	*	*	*	
Hisingeri, Edw. Brit. Cor p. 259					*		
multipora, Lons. **Pl. 40.** f. 5				*	*		
FISTULIPORA decipiens, M'Coy, Pal. Fos. p. 11					*		
GONIOPHYLLUM Fletcheri, Edw. Brit. Cor p. 290					*		
pyramidale, His. Leth. Suec. p. 101				*	*		
HALYSITES catenularius, Linn. **Foss. 20.** f. 6; **28.** f. 4; **Pl. 40.** f. 14		*	*	*	*		
escharoides, Lam. Br. Cor. p. 272. pl. 64. f. 2					*		
HELIOLITES favosus, M'Coy, Pal. Fos. p. 15			*				
Grayi, Edw. Arch. Mus. v. p. 217					*		
inordinatus, Lons. (Porites, Sil. Syst.) **Foss. 30.** f. 5; **Pl. 38.** f. 12			*				
interstinctus, Wahl. (Porites pyriformis, Sil. Syst.) **Foss. 19.** f. 3–5. **Pl. 39.** f. 2			*	*	*	*	
megastoma, M'Coy. **Foss. 30.** f. 7			*	*	*	*	
Murchisoni, M.-Edw. Brit. Fos. Cor. pl. 57. f. 6					*		
subtilis, M'Coy, Pal. Fos. p. 17				*			
tubulatus, Lons. (Porites, Sil. Syst.) **Foss. 19.** f. 1; **Pl. 39.** f. 3			*	*	*		
? discoideus (Porites, Sil. Syst) **Pl. 39.** f. 1					*		
LABECHIA conferta, Lons. **Pl. 39.** f. 5				*	*		
LONSDALEIA Wenlockensis, M'Coy, Pal. Fos. p. 34					*?		
MONTICULIPORA (Nebulipora) Bowerbanki, Edw. Brit. Fos Cor. p. 268					*		
explanata, M'Coy, Pal. Fos. p. 23			*				
favulosa, Phil. **Foss. 11.** f. 22		*					
Fletcheri, M.-Edw. **Pl. 40.** f. 9					*		
lens, M'Coy. **Foss. 13.** f. 13			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
MONTICULIPORA papillata, M'Coy, Pal. Fos. p. 24			*	*?	*	*	
Petropolitana, Pander. Edw. Brit. Fos. Cor. p. 264		*	*		*		
pulchella, M.-Edw. Brit. Fos. Cor. p. 267, pl. 42. f. 5					*		
OMPHYMA Murchisoni, Edw., **Pl. 38.** f. 2					*		
subturbinata, d'Orb. Edw. Brit. Fos. Cor. pl. 68 f. 1					*		
turbinata, Linn. (Cyathophyllum, Lons.). **Foss. 54.** f. 4, 5, **Pl. 39.** f. 11			*	*	*		
PALÆOCYCLUS Fletcheri, Edw. Arch. Mus. v. p. 205					*		
porpita, Linn. **Foss. 53.** f. 3, 4					*		
præacutus, Lons. (et lenticulatus, Lons. *non* Schlot.). **Pl. 41.** f. 4, 5				*	*		
rugosus, Edw. Arch. Mus. v. p. 206					*		
PETRAIA æquisulcata, M'Coy, Pal. Fos. p. 39			*	*			
bina, Lons. **Foss. 53.** f. 7, 8, **Pl. 38.** f. 5				*	*		
Dunoveri, Baily, G. S. Irel. Expl. Sheet 143 p. 11. f. 1				*			
elongata, Phil. **Pl. 38.** f. 6			*?	*			
rugosa, Phil. Pal. Fos. p. 7. pl. 2 f. 7c.			*	*			
subduplicata, M'Coy. **Foss. 15.** f. 11, **28.** f. 3			*	*			
uniserialis, M'Coy, Pal. Fos. p. 41			*	*			
ziczac, M'Coy, Pal. Fos. p. 60				*			
PLASMOPORA petaliformis, Lons. (Porites, Sil. Syst.) **Foss. 19.** f. 2; **Pl. 39.** f. 4			*	*	*		
scita, Edw. Brit. Fos. Cor. p. 254, pl. 59. f. 2					*		
PTYCHOPHYLLUM patellatum, Schl. (Strombodes plicatum, Lons.) **Foss. 53.** f. 5; **Pl. 38.** f. 4					*		
STROMBODES diffluens, M.-Edw. Brit. Cor. pl. 71. f. 2					*		
Murchisoni, M.-Edw. Brit. Foss. Cor. pl. 70. f. 1					*		
Philipsii, d'Orb. Brit. Cor. pl. 70. f. 2					*		
typus, M'Coy (Acervularia Balthica, Sil. Syst.) **Foss. 53.** f. 6, **Pl. 39.** f. 8					*		
SYRINGOPHYLLUM organum, Linn. **Foss. 30.** f. 4			*		*		
SYRINGOPORA bifurcata, Lons. (reticulata, Lons. *non* Goldf.) **Foss. 20.** f. 2, 4, 5; **Pl. 40.** f. 10, 11				*	*	*	
? cæspitosa, Lons. **Pl. 40.** f. 13					*		
fascicularis, Linn. (S. filiformis, et Aulopora tubæformis, Lons.) **Pl. 40.** f. 12, **Pl. 41.** f. 8				*	*		
serpens, Linn. (Aulopora serpens, conglomerata, Lons. *non* Goldf.), **Pl. 41.** f. 6, 9				*	*		
Lonsdaleana, M'Coy, Sil. Fos. p. 65			*		*		
THECIA Grayana, Edw. Brit. Foss. Cor. p. 279					*		
Swindernana, Goldf. (Porites expatiata, Sil. Syst.) **Foss. 53.** f. 1, 2; **Pl. 41.** f. 3					*	*	
ZAPHRENTIS lata, M'Coy, Pal. Fos. p. 28					*		

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
SUBKINGDOM ANNULOSA.							
Province ANNULOIDA.							
Class ECHINODERMATA.							
ACTINOCRINUS pulcher, Salt. Pal. Foss. App. p. i....					*		
Wynnei, Bail. G. S. Irel. Expl. Sh. 145. p. 10. f. 1				*			
AGELACRINUS Buchianus, Forbes. **Foss. 33.** f. 6			*				
APIOCYSTITES pentremitoides, Forbes. **Foss. 55.** f. 4					*		
CHEIROCRINUS serialis, Austin, MS.					*		
sp. with branched arms (Coll. Fletcher)					*		
COPHINUS dubius, König. (Marks of Crinoidea.) **Pl. 12.** f. 5						*	
CROTALOCRINUS rugosus, Mill. **Pl. 13.** f. 3; **Foss. 56.** f. 4–7					*		
CYATHOCRINUS arthriticus, Phil. **Pl. 14.** f. 7					*		
capillaris, Phil. **Pl. 15.** f. 3					*		
Dudleyensis, Austin, A.N.H. 1843, p. 195					*		
goniodactylus, Phil. **Pl. 14.** f. 3					*		
CYCLOCYSTOIDES Davisii, Salt. Canad. Geol. Surv. Dec. 3. pl. 10 *bis*. f. 8				*			
Marstoni, Salter, MS.			*				
DIMEROCRINUS decadactylus, Phil. **Pl. 13.** f. 5					*		
icosidactylus, Phil. **Pl. 13.** f. 4					*		
ECHINOCYSTITES pomum, Thomson, Edin. N. Ph. J. 1861, p. 109, pl. 3. f. 1–3; pl. 4. f. 1–3						*	
uva, Thomson, ibid. pl. 4. f. 4, 5						*	
ECHINO-ENCRINITES armatus, Forbes. **Foss. 55.** f. 6					*		
baccatus, Forbes, **Foss. 55.** f. 5					*		
ECHINOSPHÆRITES arachnoideus, Forbes, M. G. S. ii. p. 518			*				
Balthicus, Eichw. **Foss. 33.** f. 1			*				
Davisii, M'Coy, Pal. Fos. p. 61			*				
granatus, Wahl. **Foss. 33.** f. 5			*				
granulatus, M'Coy. **Foss. 33.** f. 3			*				
ENALLOCRINUS punctatus, His. Leth. Suec. p. 89					*		
EUCALYPTOCRINUS decorus, Phil. **Pl. 14.** f. 2					*		
granulatus, Lewis, Lond. G. J. i. pl. 21					*		
polydactylus, M'Coy, Pal. Fos. p. 58					*		
GLYPTOCRINUS? basalis, M'Coy. **Foss. 32**			*				
expansus, Phil. **Pl. 15.** f. 1, 2					*		
lævis, Portl. Geol. Rep. p. 345			*				
sp. **Pl. 10.** f. 1				*			
HEMICOSMITES oblongus, Pand.?, M. G. S. ii. p. 511			*				
pyriformis, Buch, M. G. S. ii. p. 511			*				
rugatus, Forbes, Mem. Geol. Surv. vol. ii. pt. 1. p. 302			*				
squamosus, Forbes, M. G. S. ii. p. 510			*				
ICHTHYOCRINUS pyriformis, Phil. **Pl. 14.** f. 8					*		
LEPIDASTER Grayi, Forbes, M. G. S. Decade 3. pl. 1					*		
MACROSTYLOCRINUS (Hall), sp.						*	
MARSUPIOCRINUS cælatus, Phil. **Pl. 14.** f. 1; **Foss. 56.** f. 1–3					*		
PALÆASTER asperrimus, Salt. **Foss. 34.** f. 2			*				
Caractaci, Salt. Cat. Mus. P. G. p. 30			*				
coronella, Salt. Ann. N. H. s. 2. xx. p. 326				*			
hirudo, Forbes. **Foss. 57.** f. 2						*	

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
PALÆASTER imbricatus, Salt. M.G.S. vol. iii. p. 289, pl. 23. f. 8			*				
obtusus, Forbes. **Foss. 34.** f. 1			*				
Ruthveni, Forbes. **Foss. 57.** f. 3						*	
PALÆCHINUS? Phillipsiæ. Forbes, M.G.S. ii. p. 384				*			
PALÆOCOMA Colvini, Salt. **Foss. 20.** f. 4						*	
cygnipes, Salt. Ann. N. H. s. 2. xx. p. 329						*	
Marstoni, Salt. **Foss. 21.** f. 3						*	
(Bdellacoma) vermiformis, Salter, Ann. N. H. ser. 2. xx. p. 329						*	
PALÆODISCUS ferox, Salt. A. N. H. s. 2 xx. p. 333						*	
PALASTERINA primæva, Forbes. **Foss. 57.** f. 1						*	
PERIECHOCRINUS, sp.				*			
articulosus, Aust. Ann. N. H. 1843, p. 204					*		
moniliformis, Mill. **Pl. 13.** f. 1, 2				*	*		
PISOCRINUS? ornatus, Kon. Bull. Ac. Brux. iv. p. 93					*		
pilula, Kon. Bull. Ac. Brux. iv. p. 93					*		
PLATYCRINUS retiarius, Phil. **Pl. 14.** f. 9					*		
PLEUROCYSTITES Rugeri, Salt., M.G.S. iii. pl. 23. f. 5				*			
PROTASTER leptosoma, Salt. A. N. H. s. 2. xx. p. 331						*	
Miltoni, Salt. **Foss. 21.** f. 1, 2						*	
? (Tæniaster) Salteri, Forbes, M. G. S. iii. p. 283			*				
Sedgwicki, Forbes. **Foss. 57.** f. 4						*	
PRUNOCYSTITES Fletcheri, Forbes. **Foss. 55.** f. 3					*		
PSEUDOCRINITES bifasciatus, Pearce, M.G.S. ii. p. 496					*		
magnificus, Forbes. **Foss. 55.** f. 1					*		
oblongus, Forbes, Mem. G. S. ii. p. 499					*		
quadrifasciatus, Pearce. **Foss. 55.** f. 2					*		
RHODOCRINUS? quinquangularis, Mill. Crin. p. 109; Sil. Syst. pl. 18. f. 5			*				
RHOPALOCOMA pyrotechnica, Salt. A. N. H. s. 2. xx. p. 329						*	
SAGENOCRINUS giganteus, Aust. A. N. H. 1843, p. 205					*		
SPHÆRONITES Litchi, Forbes, M. G. S. ii. p. 514			*				
munitus, Forbes. **Foss. 33.** f. 4			*				
punctatus, Forbes. **Foss. 33.** f. 2			*				
pyriformis, Forbes, M. G. S. ii. p. 515			*				
stelluliferus, Salt. M. G. S. iii. p. 287, pl. 20. f. 6 (Echino-sphærites aurantium, Forbes, M. G. S. ii. p. 516, pl. 22. f. 1)			*				
TAXOCRINUS Orbignyi, M'Coy. Pal. Fos. p. 53						*	
simplex, Phil. Sil. Syst. p. 673, pl. 18. f. 8					*		
tesseracontadactylus, His. **Pl. 14.** f. 4.					*		
tuberculatus, Mill. **Pl. 14.** f. 5					*		
TETRAMEROCRINUS formosus, Aust. A. N. H. 1843, p. 203				*?	*		

SUBKINGDOM ANNULOSA.

Province ANNULATA.

Class ANNELIDA †.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
? APHRODITA, Portl. Geol. Rep. p. 362 [Sponge ?]			*				
ARENICOLITES linearis, Hall (Scolithus). **Foss. 4.**		*					

† Some of the Burrow-marks and Trails here referred to Annelides were probably due to Crustacea. Several have formerly been regarded as Sea-weeds.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
CHONDRITES acutangulus, M'Coy, Pal. Fos. pl. 1 A; M. G. S. iii. p. 292, pl. 3. f. 4, pl. 4. f. 13		*					
informis, M'Coy, Pal. Fos. pl. 1 A; M.G.S. iii. p. 292		*					
regularis, Hark. Q. J. G. Soc. ix. p. 473			*				
CORNULITES serpularius, Schlot. **Pl. 16.** f. 3–10; **Pl. 10.** f. 2				*	*	*	
CROSSOPODIA lata, M'Coy, Pal. Fos. p. 130						*	
Scotica, M'Coy. **Foss. 42.** f. 4			*				
CRUZIANA semiplicata, Salt. M. G. S. iii. p. 291, pl. 3. f. 1–3. **Foss. 5.** f. 1–3	*						
HELMINTHOLITES, sp. Q. J. G. Soc. xv. p. 380, pl. 13. f. 28				*			
LUMBRICARIA antiqua, Portl. Geol. Rep. p. 361			*				
gregaria, Portl. Geol. Rep. p. 361			*				
MYRIANITES Macleayi, Murch. **Foss. 42.** f. 1		*	*				
tenuis, M'Coy, Pal. Fos. p. 130			*				
NEMERTITES Ollivantii, Murch. Sil. Syst. p. 701		*					
NEREITES Cambrensis, Murch. **Foss. 42.** f. 3		*					
multiforis, Harkn. Q. J. G. S. xi. p. 476		*					
Sedgwickii, Murch. **Foss. 42.** f. 2		*					
PALÆOCHORDA major, M'Coy, Pal. Fos. pl. 1 A f. 3		*					
minor, M'Coy, Pal. Fos. pl. 1 A. f. 1		*					
teres, Harkn. Q. J. G. S. xi. p. 474		*					
? PYRITONEMA fasciculus, M'Coy, Pal. Fos. p. 10		*					
SALTERELLA MacCullochii, Salt. **Foss. 28.**		*					
SCOLECODERMA antiquissima, Salter, Trans. Malvern Nat. Club, pt. 1	*						
tuberculata, Salt. M. G. S. iii. p. 293, pl. 5. f. 24	*						
SERPULITES curtus, Salt. Mem. G. S. ii. p. 333					*		
dispar, Salt. Pal. Fos. App. p. i.						*	
fistula, Holl, Q. J. G. Soc. xxi. p. 102	*						
longissimus, Murch. **Pl. 16.** f. 1					*	*	
perversus, M'Coy, Q. J. G. S. ix. p. 15					*		
SPIRORBIS Lewisii, Sow. **Pl. 16.** f. 2					*	*	
TENTACULITES Anglicus, Salt. **Pl. 1.** f. 3; **10.** f. 3; **Foss. 13.** f. 4			*	*			
ornatus, Sow. **Pl. 16.** f. 11			*	*	*		
tenuis, Sow. **Pl. 16.** f. 12						*	
TRACHYDERMA coriacea, Phil. Mem. G. S. ii. p. 331						*	
lævis, M'Coy, Pal. Fos. p. 133			*				
squamosa, Phil. Mem. G. S. ii. p. 33						*	
TRICHOIDES ambiguus, Harkn. Q. J. G. S. xi. p. 474		*					

SUBKINGDOM ANNULOSA.

Province ARTICULATA.

Class CRUSTACEA †.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ACIDASPIS Barrandii, Fletch. **Foss. 65.** f. 9					*		
hispinosa, M'Coy. **Foss. 48.** f. 6			*				
Brightii, Murch. **Foss. 65.** f. 8; **Pl. 18.** f. 7, 8			*	*	*		
callipareos, Thoms. G. J. xiii. p. 208				*			
Caractaci, Salt. G. J. xiii. p. 211, pl. 6. f. 15–17			*				

† Subgeneric names are omitted here for want of room, and they are rarely used in the text.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ACIDASPIS coronata, Salt. G. J. xiii. p. 210						*	
crenata, Emm. N. Jahr. 1845, p. 44					*		
dama, Fletch. and Salt. Morris Cat. p. 99					*		
dumetosa, Fl. and Salt. Morr. Cat. p. 99					*		
hystrix, Thoms. G. J. xiii. p. 207, pl. 6. f. 6–10			*				
Jamesii, Salter, Dec. 7. pl. 6			*				
Lalage, Thoms. G. J. xiii. p. 206, pl. 6. f. 1–8			*				
quinquespinosa, Fletch. and Salt. Morris Cat. p. 99					*		
ÆGLINA binodosa, Salt. **Foss. 9.** f. 6		*					
caliginosa, Salt. M. G. S. iii. p. 318, pl. 11. f. 10		*					
grandis, Salter. **Foss. 10.** f. 6		*					
major, Salt. Dec. G. S. 7. pl. 10. p. 4		*					
mirabilis, Forbes. **Foss. 29.** f. 3			*				
AGNOSTUS Davidis, Salt. Brit. Assoc. Rep. 1865, p. 285	*						
limbatus, Salt. M.S. (trinodus, in part, M. G. S. vol. ii. pt. 1 pl. 8. f. 11)			*				
Maccoyi, Salter (pisiformis, Sil. Syst.). **Foss. 11.** f. 5, **Pl. 3.** f. 7, 8						*	
Morei, Salt. M. G. S. Dec. 11. pl. 7. f. 13		*					
princeps, Salt. **Foss. 5.** f. 4; **10.** f. 9; **45.** f. 4	*	*					
scutalis, Salt. Br. Assoc. Rep. 1865, p. 285	*						
trinodus, Salt. **Foss. 46.** f. 6			*				
trisectus, Salt. M. G. S. Dec. 11. p. 10, pl. 1. f. 10	*						
n. sp.?. **Foss. 10.** f. 10. **p. 53**		*					
AMPHION benevolens, Salt. Monogr. Brit. Trilob. pl. 6. f. 31			*				
pauper, Salt. Brit. Trilob. pl. 6. f. 32			*				
pseudoarticulatus, Portl. Geol. Rep. p. 291			*				
AMPYX mammillatus, Sars Ibid. p. 261, pl. 1a. f. 1, 2			*				
nudus, Murch. **Foss. 48.** f. 7, **Pl. 4.** f. 9, 10		*					
parvulus, Forbes, Mem. G. S. ii. p. 350					*	*	
pennatus, Salt. Cat. Foss. M. P. G. p. 4			*				
prænuntius, Salt. **Foss. 45.** f. 6		*					
rostratus, Sars. Portl. G. R. p. 260			*				
tumidus, Forbes, Dec. G. S. 2			*				
ANGELINA Sedgwickii, Salt. **Foss. 10.** f. 2. & **45.** f. 5		*					
ANOPOLENUS Henrici, Salt. Q. J. G. Soc. xx. p. 236, pl. 13. f. 4, 5; xxi. p. 481	*						
Salteri, Hicks, Q. J. G. Soc. xxi. p. 478, p. 481, woodcut, f. 1	*						
ASAPHUS affinis, M'Coy, M. G. S. iii. p. 310, pl. 8. f. 15; pl. 12. f. 4, Salt. Mon. Br. Trilob. p. 164. pl. 24. f. 13, 14		*					
gigas, Dekay. **Foss. 29.** f. 1			*				
Homfrayii, Salt. **Foss. 45.** f. 9		*					
hybridus, Salt. Mon. Brit. Trilob. p. 153, pl. 23. f. 8–9. p. 4			*				
laticostatus, Green. Pal. Fos. p. 170		*					
Marstoni, Salt. Mon. Brit. Trilob. p. 156, pl. 23. f. 1				*			
peltastes, Salt. Mon. Brit. Trilob. p. 152, pl. 22. f. 1–4		*					

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ASAPHUS Powisii, Murch. **Foss. 46.** f. 1; **Pl. 2.** f. 2		*	*				
radiatus, Salt. M.G.S. iii. p. 311, pl. 23. f. 7			*				
rectifrons, Portl. Geol. Rep. p. 298, pl. 9. f. 1			*				
scutalis, Salt. (A. læviceps, Portl.) Mon. Brit. Trilob. p. 169, pl. 25. f. 2, 3			*				
tyrannus, Murch. **Foss. 11.** f. 1; **Pl. 1.** f. 4, 5; **2.** f. 1		*					
ASTACODERMA bicuspidatum, declinatum, planum, remiforme, serratum, spinosum, terminale, triangulare, undulatum, Harley, Q. J. G. Soc. xvii. p. 542, pl. 17.						*	*
BARRANDIA Cordai, M'Coy. Salt. Mon. Brit. Trilob. p. 142, pl. 19. f. 5		*					
longifrons, Edgell. Salter, Mon. Brit. Trilob. p. 179, f. 42, 43		*					
Portlockii, Salter, Decade Geol. Surv. 2. pl. 7. f. 1, 2, 6, 7		*					
radians, M'Coy, Brit. Pal. Fos. p. 149, pl. 1. f. 2		*					
BEYRICHIA affinis, Jones, Ann. N. H. s. 2. xvi. p. 170		*					
Barrandiana, Jones, ibid. p. 171			*				
complicata, Salt. **Foss. 11.** f. 10*; **46.** f. 7		*	*				
Klœdeni, M'Coy. **Foss. 64.** f. 4				*	*	*	*
siliqua, Jones, Ann. N. H. s 2. xvii p. 90					*	*	
Wilckensiana, Jones, ib. p. 89. **Pl. 34.** f. 21			*			*	
BRONTEUS Hibernicus, Portl. Geol. Rep. p. 270.			*				
laticauda, Wahl. Nov. Act. 8. pl. 2. f. 7, 8			*		*		
CALYMENE Blumenbachii. Brong. **Foss. 13.** f. 1; **Pl. 17.** f. 1; **18.** f. 10			*	*	*	*	
— var. Allportiana, Salt. Mon. Tril. p. 95				*	*	*	
— — Caractaci, Salt. ibid. p. 96			*				
brevicapitata, Portl. **Foss. 11.** f. 9; **46.** f. 4		*	*				
— var. Cambrensis, Salt. M. G. S. vol. iii p. 326, pl. 17. f. 13, 14			*				
duplicata, Murch. **Foss. 11.** f. 10; **Pl. 3.** f. 6		*					
obtusa, M'Coy, Sil. Fos. p. 54	*						
parvifrons, Salt. **Foss. 10.** f. 4		*					
parvifrons, var. Murchisoni, Salt. Mon. Sil. Trilob. p. 102, pl. 9. f. 26–28		*					
tuberculosa, Salt. **Foss. 64.** f. 2; **Pl. 18.** f. 11					*	*	
CARYOCARIS Wrightii, Salter, Q. J. G. S. xix. p. 137. f. 15		*					
CERATIOCARIS cassia, Salter, A. N. H. ser. 3. vol. v. p. 159						*	
decorus, Phil. M. G. S. vol. ii. pl. 30. f. 5						*	
(+Leptocheles) ellipticus, M'Coy, Pal. Fos. p. 137						*	
ensis, Salt. A. N. H. ser. 3. vol. v. p. 159						*	
inornatus, M'Coy, Pal. Fos. p. 137						*	
insperatus, Salt. M. G. S. iii. p. 295. f. 6		*					
latus, Salt. M. G. S. iii. p. 57. f. 5		*					
leptodactylus, M'Coy, Pal. Fos. p. 175.						*	
Murchisoni, Ag. **Pl. 19.** f. 1. 2						*	
papilio, Salt. **Foss. 66.** f. 1						*	
robustus, Salt. A. N. H. ser. 3. vol. v. p. 158						*	

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage Beds.
CERATIOCARIS stygius, Salt. A. N. H. ser. 3. vol. v. p. 156						*	
vesica, Salter. ibid. p. 159						*	
CHEIRURUS bimucronatus, Murch. **Foss. 65.** f. 4; **Pl. 3.** f. 5; **19.** f. 10, 11			*	*	*		
cancrurus, Salter. Dec. G. S. 7			*				
clavifrons, Dalm. **Foss. 48.** f. 1			*				
Frederici, Salter. **Foss. 45.** f. 7		*					
gelasinosus, Portl Geol. Rep p 289			*				
juvenis, Salt. M G.S. iii. p. 323. pl. 58. f. 1, 2			*				
octolobatus, M'Coy. Pal. Fos p. 154			*				
Sedgwickii, M'Coy. Pal. Fos. p. 155		*					
CONOCORYPHE abdita, Salter, M. G. S. iii. p. 306. pl. 5. f. 3	*						
applanata, Salt. Brit. Assoc. Rep. 1865. p. 285	*						
bufo Hicks, ibid. p. 285	*						
depressa, Salt. **Foss. 8.** f 2 & **45.** f 8	*						
humerosa, Salt. Brit. As. Rep. 1865. p. 285	*						
invita. Salt. M. G. S. iii. p. 305, pl. 4. f. 5 7; pl. 7. f. 1; Dec. 11. pl. 7. f. 6. **Foss. 8.** f. 1	*						
? olenoides, Salt. M. G. S iii p 308, pl. 8 f 6		*					
simplex, Salt ibid. p. 306, pl. 5. f. 17	*						
variolaris, Salt Q. J. G. S. xx. pl. 13. f. 6, 7	*						
verisimilis, Salt. M G. S. iii. p. 308, pl. 6. f. 13		*					
vexata, Salt ibid p. 307, pl. 8. f. 7		*					
CYBELE rugosa. Portl Geol. Rep p. 302			*				
verrucosa, Dalm. **Foss. 48.** f. 2		*	*				
CYPHASPIS megalops, M'Coy. **Foss. 65.** f. 2			*	*	*	*	
pygmaeus, Salter, Dec. G. S 7					*		
CYPHONISCUS socialis, Salt. **Foss. 48.** f. 8			*				
CYPRIDINA, sp. Haswell, Sil. Pentl p. 43, pl. 3. f. 13						*	
CYTHERE ? Aldensis, M'Coy, Pal. Fos. pl. 1 i. f 2			*				
? phaseolus, M'Coy (not of Hisinger), Sil. Foss. p. 58			*				
? umbonata, Salt. Pal. Fos. App. p. ii.			*				
CYTHEROPSIS ?, sp.	*		*				
DEIPHON Forbesii, Barr. S. S. Bohem. p. 814					*		
DICTYOCARIS Ramsayi, Salt. G. S. M. Expl. Sheet 32. pl. 2. f 20						*	
Slimoni, Salt. A N. H. 1866, p. 162						*	
DIKELOCEPHALUS Celticus, Salt. M. G. S. iii. p. 304, pl. 5. f. 21, 22	*	*					
discoidalis, Salt. ibid. pl 5. f. 18, 19	*						
furca, Salt. ibid. p. 303, pl. 6. f. 4; pl. 8. f. 10							
DIONIDE atra, Salt. M.G.S iii. p. 321, pl. 11A. f. 9		*					
DISCINOCARIS Browniana, H. Woodw. Q. J. G. S. xxii. pl. 25. f. 7		*					
ENCRINURUS multisegmentatus, Portl. Geol. Rep. p. 291			*				
punctatus, Brünn. **Foss. 15.** f. 10, **65.** f. 5; **Pl. 10.** f. 5				*	*	*	
sexcostatus, Salt. Dec. G. S. 7. pl. 4			*				
variolaris, Brongn. **Foss. 65.** f. 6; **Pl. 18.** f. 9					*		
ENTOMIS divisa, Jones, M.G.S. Expl. Sheet 32. p. 137						*	
impendens, Haswell, Sil. Pentl. p. 38, pl. 3. f. 11						*	

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ENTOMIS tuberosa, Jones, M. G. S. Expl. Sheet 32, p. 137, pl. 2. f. 5						*	
ERINNYS venulosa, Brit. Assoc. 1865, p. 285	*						
EURYPTERUS abbreviatus, Salt. Q. J. G. S. xv. pl. 10. f. 18						*	
acuminatus, Salt. ibid. 10. f. 17						*	
cephalaspis, Salt. Pal. Fos. App. p. v.						*	
chartarius, Salt. Q. J. G. S. xv. p. 234						*	
lanceolatus, Salt. M.G.S. Mon. I. pl. 1. f. 17						*	
linearis, Salt. Q.J.G.S. xv. pl. 10. f. 15, 16						*	*
megalops, Salt. Q.J.G.S. xv. pl. 10. f. 9-14							*
pygmæus, Salt. **Foss. 67.** f. 1						*	*
HARPES Dorani, Portl. Geol. Rep. p. 267			*				
Flanagani, Portl. **Foss. 48.** f. 4			*				
parvulus, M'Coy, Pal. Fos. pl. 1 L. f. 3			*				
HEMIASPIS limuloides, H. Woodw. Q. J. G. S. xxi p. 496, pl. 14. f. 7						*	
HOLOCEPHALINA primordialis, Salt. Q. J. G. Soc. xx. p. 237, pl. 13. f. 9	*						
HOMALONOTUS bisulcatus, Salt. **Foss. 10.** f. 5; **13.** f. 2			*	*			
cylindricus, Salt. Mon. Tril. p. 115, pl. 11. f. 12					*		
delphinocephalus, Green. **Foss. 17.** f. 1					*		
Edgelli, Salt. Mon. Tril. p. 108, pl. 10. f. 11			*				
Johannis, Salt. Mon. Tril. p. 117, pl. 12. f. 11; pl. 13. f. 1-7					*		
Knightii, König. **Pl. 19.** f. 7-9						*	
Ludensis, Salt. Mon. Tril. p. 121, pl. 12. f 1						*	
rudis, Salt. Mon. Tril. p. 109, pl. 10. f. 12-14			*				
Sedgwicki, Salt. Mon. Tril. p 107. f. 25			*				
Vulcani, Murch. **Pl. 2.** f. 3, 4		*					
HYMENOCARIS vermicauda, Salt. **Foss. 6.** f. 1	*						
ILLÆNOPSIS Thompsoni, Salt. M. G. S. iii. pl. 11 B. f. 1, 2; Mon. Tril. p. 213, pl. 20. f. 1		*					
ILLÆNUS æmulus, Salt. Mon. Tril. p. 187, pl. 28. f. 5				*			
Bailyi, Salt. Mon. Tril. p. 192, pl. 28. f. 14			*				
Barriensis, Murch. **Foss. 17.** f. 2				*	*		
Bowmanni, Salt. Monog. Tril. p. 185, pl. 28. f. 6 13			*	*			
carinatus, Salt. Mon. Tril. p. 209, pl. 27. f. 8, 9					*		
Davisii, Salter. **Foss. 46.** f. 2			*				
insignis, Hall. Salt. Mon. Tril. p. 207, pl. 27. f. 6, 7. **Pl. 17.** f. 9-11					*		
Lewisii, Salt. Mon. Tril. p. 183, pl. 26. f. 2			*				
Maccallumi, Salt. Mon. Tril. p. 210, pl. 28. f. 1; pl. 30. f. 2, 3				*			
Murchisoni, Salter, Mon. Tril. p. 201, pl. 26. f. 1; pl. 30. f. 7	*						
nexilis, Salt. Mon. Tril. p. 190, pl. 30. f. 4, 5				*			
ocularis, Salt. Mon. Tril. p. 198, pl. 29. f. 7, 8			*				
perovalis, Murch. **Pl. 4.** f. 13, 14; **23.** f. 7		*					
Portlockii, Salt. Mon. Tril. p. 197. pl. 26. f. 3, 4			*				
Rosenbergii, Eich. Salt. Mon. Tril. p. 199. pl. 29. f. 2-6			*				
Thomsoni, Salt. Mon. Tril. p. 188, pl. 28. f. 2-4; pl. 30. f. 8-10				*			

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
LEPERDITIA, sp., Ann. N. H. xvii. p. 91						*	*
punctatissima, Salt. (bupreatis, Br. Assoc. Rep. 1865, p 285)	*						
Solvensis, Jones, Ann. N. H. xvii. p. 95	*						
LICHAS Anglicus, Beyr. **Foss. 64.** f. 1					*	*	
Barrandii, Fletch. **Foss. 64.** f. 3					*		
Grayii, Fletch. G. J. vi p. 237			*		*		
hirsutus, Fletch. Q J. vi p 236					*		
laciniatus, Dalm. Pal. Fos App. p. iv			*				
laxatus, M'Coy. **Foss. 46.** f 5			*	*			
nodulosus, Salt Pal Fos. App p. iv			*				
patriarchus, Edgell Geol. Mag. iii. p. 160		*					
Salteri, Fletch Q J G. S. vi. p. 237					*		
sp (verrucosus, Salt.), M. G. S. ii. p. 340					*		
LINGULOCARIS lingulaecomes, M'Coy. M. G. S. iii pl 10. f. 1, 2		*					
MICRODISCUS punctatus, Salt. Q. J. G. Soc. xx. p. 237, pl. 13. f. 11	*						
NIOBE Homfrayi, Salt. Monogr. Brit. Trilob. p 143, pl. 20. f. 3-12		*					
OGYGIA angustissima, Salt. Monogr. Brit. Trilob. p. 129, pl. 14. f. 8, 9		*					
Buchii, Brongn. **Foss. 11.** f. 2; **Pl. 3.** f. 1, 2		*					
bullina, Salt. Mon Tril. pl. 25*. f. 5		*					
Corndensis, Murch. **Pl. 3.** f. 4		*					
peltata,* Salt. Mon. Tril. pl. 17. f. 8-10.			*				
Portlockii, Salt. **Foss. 11.** f. 3		*					
scutatrix, Salt. **Foss. 10.** f. 1		*					
Selwynii, Salt. M. G. S. iii. p. 313. **Foss. 10.** f. 8		*					
OLENUS alatus, Beck (Angelin. Pal. Suec. pt. 1)	*						
bisulcatus, Phil. **Foss. 7.** f. 2	*						
cataractes, Salt. **Foss. 45.** f. 3	*						
flagellifer, Salt. M. G. S. iii. p. 301, pl. 5 f. 8, 9	*						
humilis, Phil. **Foss. 7.** f. 1	*						
impar, Salt. M G. S. iii. p. 302, pl. 8. f. 4		*					
micrurus, Salt **Foss. 5.** f. 2; & **45.** f. 2	*						
pecten, Salt Decade G. S. 11. pl. 8, f. 12, 13	*						
scarabaeoides, Wahl (O. spinulosus, Phil.) var obesus, Salter. **Foss. 7.** f. 3	*						
serratus, Salter, Dec. G. S 11. pl. 8. f. 5	*						
PARADOXIDES aurora, Salter, Rep. Brit. Assoc. 1865, p. 285	*						
Davidis, Salter. **Foss. 45.** f. 1	*						
Hicksii, Salter, M. G. S. iii. p. 299, pl. 4. f. 12. **Foss. 6.** f. 2	*						
PARKA decipiens, Flem. (Eggs of Pterygotus)							*
PELTOCARIS aptychoides, Salt. Q. J. G. Soc. viii. p. 391, pl. 21. f. 10; xix. p. 88. f. 1		*					
Harknessi, Salt. ibid. xix. p. 89. f. 2.		*					
PHACOPS alifrons, Salt. Pal. Fos. App. p. ii			*				
amphora, Salt. Dec. G. S. 7. p. 12			*				
apiculatus, Salt. **Foss. 14.** f. 3		*	*				
Bailyi, Salt. Monogr. Brit. Trilob. p. 44, pl. 6. f. 21-24			*				
Brongniartii, Portl. Geol. Rep. p. 282.			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
PHACOPS Bucephali, Wahl. ib. p. 258, pl. 1. f. 8...			*				
caudatus, Brünn. **Pl. 17.** f. 2; **18.** f. 1				*	*	*	
conophthalmus, Beck. **Foss. 48.** f. 3; **Pl. 4.** f. 11, 12			*				
constrictus, Salter, Monogr. Brit. Trilob. p. 27, pl. 2. f. 13–16				*	*	*	
Dalmanni, Portl. Geol. Rep. p. 282			*				
Downingiæ, Murch. **Foss. 65.** f. 3; **Pl. 18.** f. 2: and 5 varieties:—α. vulgaris, Salt.; β. macrops, ib.; γ. inflatus, ib.; δ. spinosus, ib.; ζ. cuneatus, ib.				*	*	*	
? imbricatulus, Angelin. Salt. Mon. Tril. p. 48, pl. 4. f. 10				*			
Jamesii, Portl. Geol. Rep. p. 283			*				
Jukesii, Salt. Dec. G. S. 7. p. 11			*				
longicaudatus, Murch. **Pl. 17.** f. 3–6, and varr. armiger & Grindrodianus, Salt. Monogr. Trilob. pp. 56, 57, pl. 2, 3					*	*	
macroura, Sjogren. Salt. Mon. Trilob. p. 37, pl. 4. f. 18-23			*				
mimus, Salt. Mon. Brit. Trilob. p. 29, pl. 1. f. 35		*					
mucronatus, Brongn. Dec. G.S. 2. I. p. 12			*				
Murchisoni, Salt. Monog. Brit. Trilob. p. 23, pl. 2. f. 7–12					*	*	
Nicholsoni, Salt. Q. J. G. Soc. xxii. p. 486		*					
nudus, Salt. Monog. Brit. Trilob. p. 23, pl. 6. f. 19, 20					*		
obtusicaudatus, Salt. Dec. G. S. 2. I. p. 7				*			
Stokesii, Edw. **Pl. 10.** f. 6; **18.** f. 6				*	*	*	
subduplicatus, Salt. Mon. Brit. Trilob. p. 130, pl. 15. f. 7, 8				*			
truncatocaudatus, Portl. **Foss. 13.** f. 3			*				
Weaveri, Salt. Dec. G. S. 2. I. p. 7				*			
PRIMITIA bicornis, Jones, A.N.H. s.2. xvi. pl. 6. f. 23		*					
cristata, J. & H. A.N.H. s.3. xvi. pl. 13. f. 1					*		
matutina, J. & H. A.N.H. s.3. xvi. pl. 13. f. 7			*				
mundula, Jones, A.N.H. s.2. xvi. pl. 5. f. 23					*		
nana, Jones, A.N.H. s. 2. xvi. pl. 6. f. 22		*					
pusilla, J. & H. A.N.H. s.3. xvi. pl. 13. f. 11					*		
renulina, J. & H. A.N.H. s.3. xvi. pl. 13. f. 5					*		
Rœmeriana, Jones & Holl. A. N. H. s. 3 xvi. pl. 13. f. 8					*		
Salteriana, Jones, A.N.H. s.2. xvi. pl. 6. f. 20			*				
semicordata, Jones, ibid. f. 21			*				
seminulum, Jones, A.N.H. s. 2. xvi. pl. 6. f. 24					*		
simplex, Jones, ibid. pl. 6. f. 25–27; s. 3. xvi. p. 10		*					
strangulata, Salt. Q.J.G.Soc. i.; A. N. H. s. 2. xvi. pl. 6. f. 18			*				
tersa, J. & Holl, A.N.H. s. 3. xvi. pl. 13. f. 3					*		
trigonalis, Jones & Holl, ibid.					*		
umbilicata, Jones & Holl. ibid. f. 2						*	
variolata, Jones & Holl, ibid. f. 6					*		
PROETUS latifrons, M'Coy. **Foss. 65.** f. 7				*	*	*	
Stokesii, Murch. **Pl. 17.** f. 7				*	*		
PROTICHNITES Scoticus, Salter. **Foss. 24.**		*					

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
PSILOCEPHALUS inflatus, Salt. M.G.S. iii. p. 316. f. 8		*					
innotatus, Salt. M. G. S. iii. pl. 6. f. 9–12.		*					
PTERYGOTUS arcuatus, Salt. M. G. S. Mon. 1. pl. 13. f. 8, 12						*	
Banksii, Salt. ibid. pl. 12. f. 22–45. **Foss. 67.** f. 2						*	*
bilobus, Salt. ibid. pl. 1. f. 1–12. **Foss. 26.** f. 1						*	
gigas, Salt. ibid. pl. 9						*	*?
Ludensis, Salt. ibid. pl. 14. f. 1–13							*
perornatus, Salt. ibid. pl. 1. f. 13–15						*	
— var. plicatissimus, Salt. ib. f. 16						*	
problematicus, **Pl. 19.** f. 4–6					*	*	*
stylops, Salt. Monogr. pl. 12. f. 47						*	
sp., **p. 96**				*			
REMOPLEURIDES Colbii, Portl. Geol. Rep. p. 256			*				
dorso-spinifer, Portl. **Foss. 48.** f. 5			*				
latero-spinifer, Portl. Geol. Rep. p. 256			*				
longicostatus, Portl. Geol. Rep. p. 257			*				
obtusus, Salt. Dec. G. S. 7. p. 9			*				
platyceps, M'Coy, Sil. Fos. p. 44			*				
radians, Barr. S. S. Bohêm. p. 32			*				
? RIBEIRIA complanata, Salt. M. G. S. iii. pl. 11 B. f. 16. **Foss. 9.** f. 3		*					
SALTERIA involuta, Salt. M. G. S. Dec. 11. pl. 6. f. 4		*					
primaeva, Thom. Mem. Geol. Surv. Dec. 11. pl. 6. f. 1, 2		*					
SLIMONIA acuminata, Salt. **Foss. 26.** f. 6						*	
punctata, Salt. Dec. G. S. 10. pl. 10–13						*	
scorpioides, Salt. MS.						*	
SPHAEREXOCHUS mirus, Beyr. **Foss. 65.** f. 1			*	*?	*		
? boops, Salt. Mon. Tril. p. 79, pl. 6 f. 27, 28			*				
STAUROCEPHALUS globiceps, Portl. Geol. R. p. 257			*				
Maclareni (unicus), Thom. Dec. G. S. 11. V. p. 4			*				
Murchisoni, Barr. S. S. Bohêm. p. 812			*	*	*		
STYGINA latifrons, Portl. **Foss. 29.** f. 2			*				
Murchisoniae, Murch. **Foss. 11.** f. 4, **Pl. 4.** f. 1		*	*				
Musheni, Salt. Mon. Trilob. pl. 29 f. 1			*				
STYLONURUS Logani, H. Woodw. Geol. Mag. i. pl. 10. f. 1. (St. spinipes, Page)						*	
TIRESIAS insculptus, M'Coy, Sil. Fos. p. 43			*				
TRINUCLEUS concentricus, Eaton. **Foss. 11.** f. 8; **46.** f. 3; **47**; **Pl. 4.** f. 2–5		*	*				
favus, Salt. M. G. S. iii. pl. 13. f. 9		*					
fimbriatus, Murch. **Foss. 11.** f. 6, **Pl. 4.** f. 7		*					
Gibbsii, Salt. **Foss. 10.** f. 7		*					
Lloydii, Murch. **Foss. 11.** f. 7, **Pl. 4.** f. 6		*					
Murchisonii, Salt. **Foss. 9.** f. 7		*					
radiatus, Murch. **Pl. 4.** f. 8		*	*				
Sedgwickii, Salt. Sil. M. G. S. iii. pl. 12. f. 9		*					
seticornis, His. **Foss. 14.** f. 1, 2			*				
Thersites, Salt. Dec. G. S. 7			*				
Order CIRRIPEDIA.							
TURRILEPAS Wrightianus, Kon. (H. Woodw.) Q. J. G. Soc. xxi. pl. 14. f. 1–6					*		

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
SUBKINGDOM MOLLUSCA.							
Province MOLLUSCOIDA.							
Class POLYZOA †.							
BERENICEA heterogyra, M'Coy, Brit. Pal. Fos. p. 45, pl. 1 c. f. 17			*				
CELLEPORA favosa, Goldf. Pet. p. 217					*		
CERIOPORA affinis, Goldf. Pet. p. 216					*		
granulosa, Goldf. **Pl. 41.** f. 29					*		
oculata, Goldf. **Foss. 18.** f. 6					*		
CLADOGRAPSUS gracilis, Hall, Q. J. G. Soc. Dubl. 1861, pl. 4. f. 5		*					
linearis, Car. Ann. N. Hist. ser. 3. xiii. p. 24. f. 1. **Foss. 90.** f. 8		*					
CLIMACOGRAPTUS bicornis, Hall, M.G.S. iii. pl. 11 A. f. 1		*					
bullatus, Salt. Q. J. G. S. vii. pl. 10. f. 2			*				
scalaris, Linn. **Foss. 12.** f. 4		*	*				
CORYNOIDES calicularis, Nich. Geol. Mag. iv. pl. 7. f. 9–11		*					
CYRTOGRAPSUS Murchisonii, Car. **Foss. 90.** f. 1					*		
hamatus, Baily ?, Q. J. G. Soc. Dubl. 1861, pl. 4. f. 6			*				
DENDROGRAPSUS furcatulus, Salter, M. G. Surv. iii. pl. 11 A. f. 5		*					
lentus, Car. **Foss. 90.** f. 5			*				
DIASTOPORA? consimilis (Aulopora), Lons. **Foss. 20.** f. 1; **Pl. 41.** f. 7	*	*					
irregularis (Berenicea), Lons. **Pl. 41.** f. 20					*		
DICHOGRAPSUS aranea, Salt. Q.J.G.S. xix. p. 137. f. 9		*					
Sedgwickii, Salt. **Foss. 90.** f. 3		*					
DICRANOGRAPTUS ramosus, Hall. **Foss. 90.** f. 4		*					
DICTYONEMA (Graptopora) sociale, Salt. **Foss. 8.** f. 3.	*						
DIDYMOGRAPSUS (Tetragrapsus) bryonoides, Hall. Q. J. G. S. xix. p. 137. f. 8a		*					
caduceus, Salt. Geol. Journ. ix. p. 87		*					
(Tetragrapsus) crucialis, Salt. Q. J. G. S. xix. p. 137. f. 8b		*					
flaccidus, Hall. Monogr. Grapt. pl. 2. f. 17–19; Geol. Mag. iv. pl. 7. f. 2, 3		*					
Forchhammeri, Geinitz, J. G. Soc. Dublin, 1861, pl. 4. f. 7		*					
geminus, His. **Foss. 9.** f. 8		*					
hirundo, Salt. Q. J. G. Soc. xix. p. 137. f. 13		*					
Moffatensis, Car. Ann. N. Hist. ser 3. xiii. p. 25. f. 3		*					
Murchisonii, Beck. **Foss. 11.** f. 13; **12.** f. 9; **Pl. 1.** f. 1		*					
sextans, Hall, **Foss. 12.** f. 8		*					
DIPLOGRAPSUS acuminatus, Nich. Geo. Mag. iv. pl. 7. f. 16, 17		*					
barbatulus, Salt. M. G. S. iii. pl. 11 A. f. 1		*					
cometa, Gein. Verst. Grauw. pl. 1. f. 28		*					

† The Graptolites are provisionally placed under this heading, although they probably belong to the HYDROZOA (Zoophytes).

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
DIPLOGRAPSUS folium, His. **Foss. 12.** f. 4*, 6 ...	......	*					
mucronatus, Hall. Pal. N. Y. p. 268......	......	*					
pennatus, Harkn. Geol. Journ. vii. p. 62	......	*					
pristis, His. (Grapt. foliaceus, Murch.) **Pl. 1.** f. 2; **Foss. 13.** f. 14	......	*					
teretiusculus, His. **Foss. 11.** f. 14......	......	*					
tricornis, Car. Ann. N. Hist. ser. 3. p. 25. f. 2	......	*					
Whitfieldi, Hall, Pal. N. Y. iii. Supp. p. 516	......	*					
DISCOPORA antiqua, Lam. **Pl. 41.** f. 21.	......	......	......	......	*		
? favosa, Lons. **Pl. 41.** f. 22	... ..	......	......	......	*		
squamata, Lons. **Pl. 41.** f. 23..	......	......	......	......	*		
ESCHARINA ? angularis, Lons. **Pl. 41.** f. 10	......	......	......	......	*		
FENESTELLA assimilis, Lons. **Foss. 50.** f. 2; **Pl. 41.** f. 27	......	......	*	......	*		
? capillaris, Portl. Geol. Rep. p. 323 .. .	......	......	*				
Lonsdalei, d'Orb. **Foss. 50.** f. 3. (F. prisca, Lons. **Pl. 41.** f. 15-18)	......	......	......	......	*		
Milleri, Lons. **Foss. 50.** f. 4; **Pl. 41.** f. 17	...	......	*	......	*		
patula, M'Coy, Pal. Fos. p. 50	......	......	......	......	*		
regularis, Portl. Geol. Rep. p. 323	......	......	*				
reticulata, Lons. **Pl. 41.** f. 19	......	......	......	......	*		
rigidula, M'Coy, Pal. Fos. p. 50	......	......	......	......	*		
subantiqua, d'Orb. **Foss. 30.** f. 1. (F. antiqua, Lons. **Pl. 41.** f. 16)	......	......	*	......	*		
undulata, Portl. Geol. Rep. p. 322	......	......	*				
GLAUCONOME disticha, Goldf. **Foss. 50.** f. 5; **Pl. 41.** f. 12	......	......	*	......	*		
GRAPTOLITHUS Beckii, Barr. **Foss. 11.** f. 11.	......	*					
convolutus, His. Pal. Fos. p. 3; Portl. Geol. Rep. pl. 19. f. 5	......	*	*				
Conybeari, Portl. Q. J. G. S. viii. p. 391	......	......	*				
Flemingii, Salt. Geol. Journ. viii. p. 390..	......	......	......	......	*?		
Griestonensis, Nicol, Geol. Jour. vi. p. 63	......	......	*				
Hallii, Barr. Grapt. Boh. pl. 2. f. 12-15	...	*					
Hisingeri, Car. (sagittarius, His. *non* Linn.) Geol. Journ. viii. pl. 21. f. 8..	....	*					
latus, M'Coy, Pal. Fos. p. 4...............	.....	*					
Nilssoni, Barr. Geol. Journ. vii. p. 61..	....	*					
priodon, Bronn. (G. Ludensis, Sil. Syst.) **Foss. 12.** f. 3; **13.** f. 15; **Pl. 12.** f. 1	.....		*	*	*	*	
Salteri, Gein. Geol. Journ. vii. pl. 10. f. 1	...		*				
Sedgwickii, Portl. **Foss. 12.** f. 2	.....	*	*				
tenuis, Portl. **Foss. 11.** f. 12	..	*					
HETEROPORA ? crassa, Lons. **Pl. 41.** f. 14......	..	.. ..		.. .	*		
PHYLLOGRAPTUS angustifolius, Hall, Q. J. G. Soc. xix. p. 137. f. 7. **Foss. 90.** f. 7	..	*					
PHYLLOPORA ? Hisingeri, M'Coy. **Foss. 28.** f. 6	....	.....	*				
POLYPORA ? crassa, Lons. (Hornera, Sil. Syst.) **Foss. 50.** f. 1, **Pl. 41.** f. 13.	....	.. ..	..	...	*		
PROTOVIRGULARIA dichotoma, M'Coy, Pal. Fos. p. 10	..	*					
PTILODICTYA acuta, Hall. **Foss. 30.** f. 2	.. .	..	*				
costellata, M'Coy, Pal. Fos. p. 46	.....	.. .	*				
dichotoma, Portl. **Foss. 31.** f. 5	....	. .	*	*			
explanata, M'Coy, Pal. Fos. p. 46	....	. ..	*				
fucoides, M'Coy, Pal. Fos. p. 47	......	......	*				
lanceolata, Goldf. **Foss. 50.** f. 6; **Pl. 41.** f. 11......................................	......	......	*	*	*		
scalpellum, Lons. **Foss. 51; Pl. 41.** f. 25	......	......	......	*	*		

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
RASTRITES Linnæi, Barr. Grapt. Bohêm. pl.4.f.2-4		*					
maximus, Carr. **Foss. 90.** f. 6		*					
peregrinus, Barr. **Foss. 12.** f. 1		*					
RETEPORA ? infundibulum, Lons. **Pl. 41.** f. 24					*		
RETIOLITES Geinitzianus, Barr. **Foss. 90.** f. 2					*		
venosus, Hall, Pal. N. York, ii. p. 40					*		

SUBKINGDOM MOLLUSCA.

Province MOLLUSCOIDA.

Class BRACHIOPODA.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ATHYRIS compressa, Sow. **Pl. 22.** f. 22					*		
? depressa, Sow. (Rhynchonella). **Pl. 22.** f. 17			*	*	*		
obovata, Sow. **Pl. 22.** f. 16					*	*	
ATRYPA Barrandii, David. Bull. Soc. Géol. Fr. ser. 2. v. p. 332, pl. 3. f. 32				*	*		
? Grayii, Dav. **Foss. 58.** f. 3			*	*	*		
Headii, Bill., var. Anglica, Dav. Mon. Sil. Brach. pl. 22. figs. 1-7			*				
hemisphærica, Sow. **Foss. 15.** f. 4; **Pl. 9.** f. 3				*			
imbricata, Sow. **Pl. 22.** f. 19 (part)					*		
marginalis, Dalm. **Pl. 9.** f. 2; **22.** f. 19			*	*	*		
orbicularis (var. of A. reticularis), Sow. **Pl. 9.** f. 4, 5				*			
reticularis, Linn. **Foss. 15.** f. 5; **Pl. 9.** f. 1; **21.** f. 12, 13				*	*	*	
CHONETES lata, von Buch. **Pl. 20.** f. 8; **34.** f. 18				* ?	*	*	
minima, Sow. **Pl. 20.** f. 16				*	*		
striatella, Dalm. (Orthis) Sil. Syst. pl. 3 f. 10 *b*; pl. 5. f. 13						*	
CRANIA catenulata, Salt. G. S. Irel. Expl. Sheet 35 NE, p. 9. f. 3			*				
craniolaris, M'Coy, Pal. Foss. p. 255					*		
divaricata, M'Coy. **Foss. 38.** f. 2			*				
Grayii, Dav. Mon. Brach. pl. 8. f. 22-24					*		
implicata, Sow. Dav. Mon. Brach. pl. 8. f. 13-18; pl. 20. f. 4				*	*	*	
Sedgwickii, Lewis. Dav. Bull. Soc. Géol. Fr. ser. 2. v. p. 334					*		
Siluriana, Dav. Mon. Brach. pl. 8. f. 19, 20					*		
DISCINA crassa, Hall, Pal. N. Y. i. p. 290			*				
elongata, Portl. Geo. Rep. pl. 32. f. 10			*				
labiosa, Salt. Br. Assoc. Rep. 1865, p. 285	*						
Morrisii, Dav. Bul. S. G. Fr. v. p. 334					*		
oblongata, Portl. Geol. Rep. p. 445			*				
pileolus, Hicks, Brit. Assoc. Rep. 1865, p. 285	*						
punctata, Sow. (Orbicula, Sil. Syst.). **Foss. 38.** f. 1; **Pl. 5.** f. 17			*				
rugata, Sow. **Pl. 20.** f. 1, 2; **35.** f. 27					*	*	
Siluriana, Dav. Mon. Brach. p. 6. f. 8			*				
striata, Sow. **Pl. 20.** f. 3						*	
Verneuilii, Dav. Bul. S. G. Fr. v. p. 334					*		
LEPTÆNA calcarata, M'Coy, Sil. Fos. pl. 3. f. 9				*	*		
Fletcheri, Dav. Bull. Soc. Géol. Fr. v. p. 319, pl. 111. f. 12			*	*	*		

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
LEPTÆNA lævigata, Sow. **Pl. 20.** f. 15					*	*	
lævissima, M'Coy, Sil. Fos. p. 27					*		
oblonga, Pander. Geol. Russ. pl. 15. f. 2			*				
quinquecostata, M'Coy. **Foss. 34.** f. 3			*				
scissa, Salter, MS. **p. 210**				*			
sericea, Sow. **Foss. 33.** f. 6; **Pl. 5.** f. 14; **9.** f. 18		*	*	*	*?		
sublævis, M'Coy, Sil. Fos. p. 35			*				
tenuicincta, M'Coy **Foss. 37.** f. 4		*	*				
tenuissimestriata, M'Coy, Pal. Fos. pl 1H. f. 44		*	*				
transversalis, Dalm. (L. Duvalii, Dav. Bul. S. G. Fr. v. p. 317.) **Pl. 9.** f. 17; **20.** f. 17			*	*	*		
ungula, M'Coy. Pal. Fos. p. 249			*				
LINGULA attenuata, Sow. **Foss. 11.** f. 18; **Pl. 5.** f. 16.		*					
Bechei, Salt. Dav. Mon. Brach pl 1. f. 12, 13		*					
brevis, Portl. Geol. Rep. p. 443			*				
cornea, Sow. **Foss. 23.** f. 3; **25.** f. 8; **Pl. 34.** f. 2						*	*
crumena, Phil. **Foss. 13.** f. 5				*			
curta, Conrad, Dav Mon. Brach. pl. 3. f. 33							
granulata, Phil. **Foss. 11.** f. 19; **38.** f. 4		*					
lata, Sow. **Pl. 20.** f. 6						*	
Lewisii, Sow. **Pl. 20.** f. 5					*	*	
longissima, Pand.? Pal. Fos. p. 252			*				
minima, Sow. Sil. Syst. pl. 5. f. 23						*	
obtusa, Hall, Pal. N. York, p. 9?		*					
ovata, M'Coy, Sil Fos. p. 24			*				
parallela, Phil M. G. S ii. pt. 1. p. 370				*			
pygmæa, Salt Q.J.G. Soc. xxi p. 101. f. 8	*						
Ramsayi, Salt. **Foss. 11.** f. 20		*					
striata, Sow. **Pl. 20.** f 7						*	
Symondsii Salt. Dav Mon. Sil Brach. pl. 3. f. 7–17				*	*	*	
squamosa. Holl. Q J. G. Soc xxi. p. 102	*						
tenuigranulata, M'Coy. **Foss. 38.** f. 5.			*				
LINGULELLA Davisii. M'Coy **Foss. 5.** f. 1, **10.** f. 11	*						
lepis. Salt. M. G S. iii. p. 334 f 11	*	*					
unguiculus. Salt. Brit. Assoc. Rep. 1865	*						
MERISTELLA angustifrons, M'Coy (Rhynchonella). **Foss. 42.** f. 2				*			
Circe, Barr. (Terebratula), Bull. Soc. Géol. Fr. ser. 2. v. p. 326					*		
? crassa, Sow. (Atrypa). **Pl. 9.** f. 6–8			*	*			
? didyma, Dalm. (Rhynch.). **Pl. 22.** f. 15				*	*	*	
? furcata, Sow. (Rhynch.). **Pl. 9.** f. 12, 13				*			
nitida, Hall (Terebratula læviuscula, Sow.). **Pl. 22.** f. 14					*		
Maclareni, Haswell, Sil. Fos. Pent. Hills, pl. 2. f. 16					*		
? subundata, M'Coy (Rhynch.), Pal. Fos. p. 207				*			
tumida, Dalm. (Atrypa). **Pl. 22.** f. 20				*	*	*	
NUCLEOSPIRA pisum, Sow. (Spirifer). **Pl. 22.** f. 7					*		
OBOLELLA maculata, Salt. Brit. Assoc. Rep. 1865, p. 285	*						

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
OBOLELLA Phillipsii, Holl, Q. J. G. Soc. xxi. p. 101. fig. 10	*						
Phillipsii, var. Salteri, Holl, ib. fig. 9	*						
plumbea, Salt. **Foss. 9.** f. 1		*					
sagittalis, Salt. Br. A. Rep. 1865, p. 285	*						
OBOLUS Davidsoni, Salt. Dav. Clas. Brach. p. 136				*	*		
transversus, Salt. Dav. Clas. Brach. p. 136					*		
Woodwardii, Salt. Dav. Mon. Sil. Brach. pl. 5. f. 8					*		
ORBICULOIDEA Beckettiana, Dav. Mon. Sil. Brach. p. 75, pl. 7. f. 19					*		
Forbesii, Dav. ibid. pl. 7. f. 14–18					*		
ORTHIS Actoniæ, Sow. **Foss. 35.** f. 2; **Pl. 5.** f. 11		*	*	*			
æquivalvis, Dav. Bul. S. G. Fr. v. p. 321				*			
alata, Sow. (Spirifer, Sil. Syst.) **Foss. 11.** f. 15; **Pl. 5.** f. 6			*				
alternata, Sow. **Pl. 6.** f. 5			*				
biforata, Schl. **Foss. 36.** f. 4; **37.** f. 1		*	*	*	*		
biloba, Linn. **Pl. 9.** f. 20; **20.** f. 14			*	*	*		
Bouchardii, Dav. **Foss. 59.** f. 1				*	*		
calligramma, Dalm. **Foss. 10.** f. 12; **Pl. 5.** f. 7–9; **9.** f. 21; **20.** f. 10		*	*	*	*		
— var. calliptycha, M'Coy, M. G. S. iii. pl. 22. f. 2			*				
— var. plicata, Sow. Sil. Syst. pl. 5. f. 7; M. G. S. iii. pl. 22. f. 5			*				
— var. proava, Salt. Mem. Geol. Surv. iii. pl. 22. f. 1		*					
— var. simplex, M'Coy, M. G. S. iii pl. 22 f. 4			*				
— var. virgata, Sow. M. G. S. iii. pl. 22. f. 3			*				
— var. Walsallensis, Dav. M. G. S. iii. pl. 22. f. 6 7		*	*				
Carausii, Salter, MS.		*					
confinis, Salt. Q. J. G. S. v. p. 15, pl. 1. f. 4		*					
costata, Sow. Sil. Syst. p. 639			*				
crispa, M'Coy, Sil. Fos. p. 29			*	*?			
Davidsoni, Vern. **Foss. 59.** f. 2				*	*		
elegantula, Dalm. **Pl. 5.** f. 5; **9.** f. 19; **20.** f. 12		*	*	*	*	*	
— var. orbicularis, Sow. **Pl. 20.** f. 9					*	*	
fallax, Salt. Sil. Fos. Irel. p. 72			*				
filosa, Sow. **Pl. 20.** f. 21					*	*	
flabellulum, Sow. **Foss. 35.** f. 1; **Pl. 5.** f. 12			*				
Hicksii, Salter, MS.	*						
Hirnantensis, M'Coy. Pal. Fos. p. 219			*				
hybrida, Sow. **Pl. 20.** f. 13			*	*	*		
insularis, Eichw. Geol. Russ. ii. pl. 8. f. 7			*	*			
intercostata, Portl. Geol. Rep. p. 454			*				
interplicata, M'Coy, Sil. Fos. p. 31			*				
lata, Sow. (et O. protensa, Sow.) **Pl. 9.** f. 22, 23			*	*			
lenticularis, Dalm. M. G. S. iii. pl. 4. f. 8–10	*						
Lewisii, Dav. Bull. S. G. Fr. v. p. 323					*		
lunata, Sow. **Pl. 20.** f. 11; **35.** f. 29			*				
polygramma, Sow. Sil. Syst. pl. 21. f. 4*a*			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ORTHIS porcata, M'Coy. **Foss. 36.** f. 5			*	*	*		
radians, Sow. **Pl. 5.** f. 10			*				
remota, Salt. **Foss. 10.** f. 13		*					
reversa, Salt. **Foss. 49.** f. 3				*			
rustica, Sow. Sil. Syst. p. 624				*	*		
sagittifera, M'Coy. Pal. Fos. p. 227			*	*?			
semicircularis, Sow. Sil. Syst. p. 639			*				
simplex, M'Coy. Sil. Fos. p. 34			*				
spiriferoides, M'Coy. **Foss. 37.** f. 2		*	*				
striatula, Emmons. **Foss. 11.** f. 16; **33.** f. 3		*					
testudinaria, Dalm. **Foss. 13.** f. 6; **Pl. 5.** f. 1, 2			*	*			
triangularis, Sow. **Pl. 5.** f. 13		*					
tricenaria, Conrad. Hall, Pal. N. Y. i. p. 121			*	*			
turgida, M'Coy, Pal. Fos. p. 220		*	*				
unguis Sow. **Pl. 5.** f. 3, 4			*				
vespertilio, Sow. **Foss. 13.** f. 7, **Pl. 6.** f. 1-3			*	*			
ORTHISINA ascendens, Pand. M'Coy, Pal. Fos. p. 231			*				
Scotica, M'Coy, Pal. Fos. p. 232			*				
PENTAMERUS galeatus, Dalm. **Pl. 21.** f. 8, 9					*	*	
globosus, Sow. **Pl. 8.** f. 8				*			
Knightii, Sow. **Pl. 21.** f. 10, var. f. 11					*	*	
linguifer, Sow. **Pl. 22.** f. 21				*	*		
oblongus, Sow. **Foss. 15.** f. 2; **Pl. 8.** f. 1-4				*			
— var. (P. lævis, Sow. Sil. Syst. pl. 19. f. 9)				*			
rotundus, Sow. **Pl. 22.** f. 18					*		
undatus, Sow. **Foss. 14.** f. 6. **Pl. 8.** f. 5-7				*			
PORAMBONITES? Capewellii, Dav. **Foss. 58.** f. 6					*		
intercedens, Pand. Beitr. pl. 11. f. 2				*			
RETZIA? Barrandei, Dav. Bul S. G. Fr. s. 2. p. 332					*		
Baylei, Dav. **Foss. 57.** f. 9					*		
Bouchardi, Dav. **Foss. 58.** f. 4					*		
Salteri, Dav. **Foss. 58.** f. 7, 8					*		
RHYNCHONELLA borealis, Schl. **Pl. 22.** f. 4; var. f. 5				*	*		
cuneata, Dalm. **Pl. 22.** f. 8				*	*		
Davidsoni, M'Coy, Pal. Fos. p. 200					*	*	
decemplicata, Sow. **Pl. 9.** f. 15				*	*		
deflexa, Sow. **Pl. 22.** f. 10					*		
Lewisii, Dav. **Foss. 58.** f. 2				*	*	*	
Llandoveriana, Dav. (serrata, M'Coy). **Foss. 49.** f. 1				*			
nasuta, M'Coy. Pal. Fos. p. 203			*				
navicula, Sow. **Pl. 22.** f. 12					*	*	
neglecta, Sow. **Pl. 9.** f. 14				*			
nucula, Sow. **Foss. 58.** f. 1; **Pl. 9.** f. 9, 11; **22.** f. 1, 2				*	*	*	
obtusiplicata, Hall, Pal. N. York, p. 269				*			
Pomelii, Dav. Bull. S. G. Fr. ser. 2. v. p. 330					*		
sexcostata, M'Coy, Sil. Fos. p. 41				*			
sphæroidalis, M'Coy, Pal. Fos. p. 206					*		
Stricklandii, Sow. **Pl. 22.** f. 11					*		
tripartita, Sow. **Pl. 9.** f. 10				*			
Wilsoni, Sow. **Pl. 22.** f. 13				*	*	*	
SIPHONOTRETA Anglica, Morr. **Foss. 58.** f. 10					*		

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
SIPHONOTRETA micula, M'Coy. **Foss. 11.** f. 17;		*					
38. f. 3					*	*	
SPIRIFER bijugosus, M'Coy, Sil. Fos. Irel. p. 36				*	*	*	
crispus, His. **Pl. 21.** f. 4				*	*	*	
elevatus, Dalm. **Pl. 21.** f. 5, 6							
exporrectus, Wahl. (trapezoidalis, Dalm.).				*	*	*	
Pl. 9. f. 24; **21.** f. 3				*	*	*	
plicatellus, Linn. **Pl. 9.** f. 25; **21.** f. 1, 2							
sulcatus, His. Dav. Bull. Soc. Géol. Fr.					*		
ser. 2. v. p. 325, pl. 3. f. 41							
STRICKLANDINIA lens, Sow. (Pentamerus). **Foss.**				*			
15. f. 1; **Pl. 8.** f. 9--11				*	*		
lirata, Sow. (Pentamerus). **Foss. 15.** f. 3							
STROPHOMENA alternata, Conr. Pal. N. York, p. 102			*	*			
(bipartita, Salt., included)							
antiquata, Sow. **Foss. 59.** f. 8; **Pl. 20.**			*	*	*		
f. 18				*	*		
applanata, Salt. M. G. S. ii. p. 380				*			
arenacea, Salt., **p. 210**			*				
complanata, Sow. Sil. Syst. p. 636							
compressa, Sow. **Foss. 15.** f. 7; **Pl.**				*	*		
9. f. 16			*				
concentrica, Portl. Geol. Rep. p. 452			*	*			
corrugata, Portl. Geol. Rep. p. 450			*				
deltoidea, Conr. Pal. N. York, p. 106			*	*	*	*	
depressa, Dalm. **Pl. 20.** f. 20				*	*	*	
euglypha, Dalm. **Pl. 20.** f. 19			*				
expansa, Sow. **Foss. 36.** f. 2; **Pl. 6.** f. 4				*	*		
funiculata, M'Coy. **Foss. 59.** f. 4, 5							
grandis, Sow. (cancellata, Portl.). **Foss.**			*				
13. f. 9; **Pl. 6.** f. 6, 7					*		
imbrex, Pand. **Foss. 59.** f. 6, 7							
Orbignyi, Dav. (Orthis) Bull. Soc. Géol.					*		
Fr. ser. 2. v. p. 320, pl. 3. f. 17					*		
Ouralensis, Vern. Geol. Russ. pl. 14			*	*	*		
pecten, Linn. **Foss. 59.** f. 3			*				
simulans, M'Coy, Pal. Fos. p. 246							
tenuistriata, Sow. **Foss. 13.** f. 8; **Pl. 5.**			*				
f. 15					*		
undata, M'Coy, Pal. Fos. p. 234							
SUBKINGDOM MOLLUSCA.							
Province LAMELLIBRANCHIATA.							
Class CONCHIFERA.							
(Monomyaria.)							
AMBONYCHIA acuticosta, M'Coy. Pal. Fos. p. 264					*		
carinata, Conr. Hall, Pal. New York, i.			*				
p. 294			*				
gryphus, Portl. Geol. Rep. p. 455			*				
transversa, Portl. Geol. Rep. p. 746			*				
trigona, Portl. Geol. Rep. p. 422			*				
Triton, Salt. **Foss. 39.** f. 8			*				
undata, Hall, Pal. N. York, p. 165					*	*	
AVICULA ampliata, Phil. M. G. S. ii. p. 367						*	
Danbyi, M'Coy. **Foss. 60.** f. 2, 3					*		
PTERINEA asperula, M'Coy. **Foss. 60.** f. 4							

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
PTERINEA Boydii, Conr. Pal. Fos. p. 259						*	
bullata, M'Coy, Sil. Fos. p. 23				*			
demissa, Conr. (var. of retroflexa, His.)				*	*	*	
fimbriata, M'Coy, Sil. Fos. p. 21					*		
hians, M'Coy, Pal. Fos. p. 260						*	
lineata, Goldf. Pet. G. pl. 119. f. 6 ?						*	
lineatula, d'Orb. **Pl. 23.** f. 16				*	*	*	
megaloba, M'Coy. Pal. Fos. p. 261						*	
mira, Barrande, MS. p. 228					*		
orbicularis, M'Coy, Sil. Fos. p. 21					*		
panopææformis. M'Coy. Sil Fos. p. 22 (also posidoniæformis, M'Coy)					*		
? planulata, Conr. M. G. S. ii. p. 368				*	*	*	
pleuroptera, Conr. Pal. Fos. p. 261			* ?		*	*	
rectangularis, Sow. **Pl. 34.** f. 4				*		*	
retroflexa, Wahl. (squamosa, M'Coy). **Pl. 9.** f. 26; **23.** f. 17				*	*	*	
Sowerbyi, M'Coy. **Pl. 23.** f. 15					*	*	
subfalcata, Conr. Pal. Fos p. 263					*	*	
sublævis, M'Coy, Sil. Fos. Irel. p. 23				*			
tenuistriata, M'Coy. **Foss. 60.** f. 5			*		*	*	
(Dimyaria.)							
ANODONTOPSIS angustifrons, M'Coy. Pal. Fos. p. 271						*	
bulla, M'Coy. **Foss. 61.** f. 5				*		*	
lævis. Sow. (Pullastra, Sil. Syst.), Pal. Fos. p. 271						*	
lucina, Salt. M. G. S. Expl. Sheet 32. p. 140, pl. 2. f. 14						*	
perovalis, Salt. Mem. G. S. ii. p 363						*	
quadratus, M'Coy. Pal. Fos p. 272						*	
ARCA ? Edmondiæformis. M'Coy, Pal. Fos. p. 283			*			*	
? primitiva. Phil. Mem. G. S. ii. p. 366						*	
CARDIOLA fibrosa, Sow. **Pl. 23.** f. 11					*	*	
interrupta, Sow **Pl. 23.** f. 12			*		*	*	
semirugata, Portl Geol. Rep. p 430			*				
? striata, Sow. **Pl. 23** f. 13					*	*	
CLEIDOPHORUS ovalis. M'Coy, Pal. Fos. p. 273			*	* ?	*		
planulatus. Conr Pal Fos. p. 273					*		
CTENODONTA (Nucula, Arca, &c.) ambigua, Portl Geol. Rep. p 430 (and Pectunculus Appolini. Portl)			*				
Anglica, d'Orb. **Pl. 23.** f. 10				*	*	*	
deltoidea, Phil. Mem. G S. ii. p. 366				*			
dissimilis, Portl. Geol. Rep. p. 428			*				
Eastnori. Sow. **Pl. 10.** f. 9				*			
lævis, Sow. **Pl. 7.** f. 3			*				
lingualis, Phil. M. G. S. ii. p. 367				*			
obesa, Salt. M. G. S. Expl. Sheet 32. pl. 2. f. 11, 12						*	
obliqua, Port. **Foss. 39.** f. 6			*				
poststriata, Emmons, Pal. N. Y. i. p. 151					*		
quadrata. M'Coy, Sil. Fos. p. 20			*				
radiata, Portl. Geol. Rep. p. 430			*				
regularis, Portl. Geol. Rep. p. 427			*				
rhomboidea, Phil. Mem. G. S. ii. p. 367				*			
scitula, M'Coy, Sil. Fos. p. 20			*				
semitruncata, Portl. Geol. Rep. p. 429			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
CTENODONTA subacuta, M'Coy, Sil. Fos. p. 19			*				
subæqualis, Sow. **Pl. 10.** f. 7, 8				*		*	
subcylindrica, M'Coy, Sil. Fos. p. 19				*			
sulcata, His. Leth. Suec. Suppl. II. p. 3, pl. 40. f. 2				*	*	*	
thracioides, Salt. M. G. S. Expl. Sheet 32. pl. 2. f. 13						*	
transversa, Portl. Geol. Rep. p. 427 (and Arca subtruncata, id.)			*				
varicosa, Salt. **Foss. 39.** f. 4			*				
CUCULLELLA angulata, Baily, G.S. Irel. Expl. Sheet 135. p. 13. f. 4			*				
antiqua, Sow. **Pl. 34.** f. 16			* ?	*		*	
Cawdori, Sow. **Pl. 34.** f. 3						*	
coarctata, Phil. M. G. S. ii. pt. 1. p. 366						*	
ovata, Sow. **Pl. 34.** f. 17				*		*	
DOLABRA ? elliptica, M'Coy, Pal. Fos. p. 269						*	
obtusa, M'Coy, Pal. Fos. p. 270						*	
GONIOPHORA cymbæformis, Sow. **Pl. 23.** f. 2; **34.** f. 15				*		*	
sp.				*			
GRAMMYSIA cingulata, His. **Foss. 61.** f. 1					*	*	
extrasulcata, Salt. M. G. S. ii. pt. 1. pl. 361						*	
rotundata, M'Coy, Pal. Fos. p. 281						*	
triangulata, Salt. **Foss. 61.** f. 2						*	
LUNULACARDIUM elegans, Salt. M. G. S. Expl. Sheet 32. pl. 2. f. 10						*	
LYRODESMA cuneata, Phil. Mem. G. S. ii. p. 366				*			
plana, M'Coy. **Foss. 39.** f. 5			*				
MEGALOMUS, sp. **p. 196**			*				
MODIOLOPSIS antiqua, Sow. **Pl. 23.** f. 14					*		
complanata, Sow. **Pl. 23.** f. 1						*	
expansa, Portl. **Foss. 39.** f. 2			*				
gradata, Salter. **Foss. 61.** f. 8					*	*	
inflata, M'Coy, Pal. Fos. p. 266			*				
modiolaris, Conr. **Foss. 39.** f. 3			*				
Nerei, Portl. Geol. Rep. p. 424			*				
obliqua, Sow. **Pl. 7.** f. 2			*				
orbicularis, Sow. **Pl. 7.** f. 1			*	*			
perovalis, Salt. Mem. G. S. ii. pt. 1. p. 263						*	
platyphylla, Salt. **Foss. 61.** f. 7						*	
postlineata, M'Coy. **Foss. 39.** f. 1			*				
pyrus, Salt. M. G. S. iii. p. 342, woodcut			*				
quadrata, Salt. Mem. G. S. ii. p. 363						*	
securiformis, Portl. Geol. Rep. p. 425						*	
MYTILUS Chemungensis, Conr.? M. G. S. ii. p. 365					*		
cinctus, Portl. Geol. Rep. p. 426			*				
exasperatus, Phil. Mem. G. S. ii. p. 364					*		
mytilimeris, Conr. **Foss. 61.** f. 6			* ?	*	*	*	
unguiculatus, Salt. Mem. G. S. ii. p. 365			*		*		
ORTHONOTA amygdalina, Sow. **Pl. 23.** f. 6, var. f. 7				*		*	
angulifera, M'Coy. **Foss. 61.** f. 3						*	
globulosa, M'Coy, Pal. Fos. p. 278						*	
impressa, Sow. **Pl. 23.** f. 3				*		*	
inornata, Phill. M. G. S. vol. ii. pl. 19. f. 3				*			
nasuta, Conr. **Foss. 13.** f. 12			*				
prora, Salt. **Foss. 61.** f. 4. (semisulcata, M'Coy)						*	

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ORTHONOTA rigida, Sow. **Pl. 23.** f. 8				*		*	
rotundata, Sow. **Pl. 23.** f. 5				*		*	
semisulcata, Sow. (Modiola), Sil. Syst. p. 617			*	*		*	
solenoides, Sow. **Pl. 23.** f. 9						*	
truncata, M'Coy, Pal. Fos. p. 279						*	
undata, Sow. **Pl. 23.** f. 4					*?	*	
PALÆARCA amygdalus, Salt. M.G.S. iii. pl. 11 B. f. 17		*					
Billingsiana, Salt. M. G. S. iii. p. 342. woodcut 12. f. 4		*					
bulla, Salt. M. G. S. iii. p. 343. woodcut 13. f. 3			*				
modiolaris, Salter, M. G. S. iii. p. 342. woodcut 12. f. 2			*				
obscura, Salt. M. G. S. iii. p. 343. woodcut 13. f. 2			*				
quadrata, Salt. M. G. S. iii. p. 342. woodcut 12. f. 3			*				
socialis, Salt. M. G. S. iii. p. 344, pl. 11 A. f. 13		*					
PLEURORHYNCHUS æquicostatus, Phil. **Foss. 60.** f. 1					*		
calcis, Bail. G.S. Ir. Expl. Sh. 145. p. 11. f. 2		*					
dipterus, Salt. **Pl. 36.** f. 7			*				
pristis, Salt. Sil. Fos. Irel. p. 71				*			
PSEUDAXINUS securiformis, M'Coy, Pal. Fos. p. 272						*	
REDONIA Anglica, Salt. **Foss. 9.** f. 2		*				*	
TELLINITES affinis, M'Coy, Brit. Pal. Fos. pl. 1 K. f. 31							*

SUBKINGDOM MOLLUSCA.

Province ODONTOPHORA.

Class GASTEROPODA.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ACROCULIA antiquata, Salt. M.G.S. Expl. Sheet 32. p. 141, pl. 2. f. 17						*	
euomphaloides, M'Coy, Pal. Fos. p. 290						*	
haliotis, Sow. **Pl. 24.** f. 9				*	*		
prototypa, Phil. **Pl. 24.** f. 8					*		
CHITON Grayanus, Koninck. Bul. Ac. Brux. iii. f. 1					*		
Griffithii, Salter (Helminthochiton). **Foss. 40.** f. 8				*			
CYCLONEMA concinna, M'Coy, Sil. Fos. p. 12			*				
corallii, Sow. **Pl. 24.** f. 1						*	
crebristria, M'Coy, Pal. Fos. p. 295			*				
octavia, d'Orb. **Pl. 24.** f. 4						*	
quadristriata, Phil. Mem. G. S. ii. p. 388				*			
rupestris, Eichw. **Foss. 40.** f. 4			*				
sulcifera, Eichw., Urw. Russl. pl. 2. f. 14			*				
undifera, M'Coy, Pal. Fos. p. 306						*	
ventricosa, Hall, Pal. N. York, ii. p. 90				*			
EUOMPHALUS alatus, His. **Pl. 25.** f. 4					*	*	
carinatus, Sow. **Pl. 24.** f. 11						*	
centrifugus, Wahl. M'C. Pal. Fos. p. 297					*	*	
Corndensis, Sow. **Pl. 7.** f. 5		*					
discors, Sow. **Pl. 24.** f. 12					*		
funatus, Sow. **Pl. 25.** f. 3				*	*	*	
lautus, M'Coy. Sil. Fos. p. 14				*	*		
prænuntius, Phil. Mem. G. S. ii. p. 357				*			

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
EUOMPHALUS rugosus, Sow. **Pl. 24.** f. 13					*		
sculptus, Sow. **Pl. 9.** f. 27; **25.** f. 2			*	*	*	*	
subcarinatus, Münst. M'Coy, Sil. Fos. Irel. p. 14				*			
tubæformis, Baily, G. S. Irel. Expl. Sheet 10. p. 10. f. 6			*				
HOLOPEA carinata, Forbes, M. G. S. iii. p. 348. woodcut 14. f. 4			*				
concinna, M'Coy. **Foss. 40.** f. 5			*				
conica, Forbes, M. G. S. iii. p. 348. woodcut 14. f. 2			*				
constricta, M'Coy, Brit. Pal. Fos. pl. 1 K. f. 41			*				
exserta, Forbes, M.G.S. iii. p. 347. woodcut 14. f. 1			*				
lymnæoides, Forbes, M. G. S. iii. p. 348. woodcut 14. f. 3			*				
striatella, Sow. (Trochus constrictus, M'Coy). **Pl. 7.** f. 4			*				
HOLOPELLA cancellata, Sow. **Foss. 15.** f. 8; **Pl. 10.** f. 14			*	*		*	
conica, Sow. **Pl. 34.** f. 10; **Pl. 35.** f. 26				*		*	
gracilior, M'Coy, Pal. Fos. p. 303					*		
gregaria, Sow. **Pl. 34.** f. 10 *a*					*	*	
intermedia, M'Coy, Pal. Fos p. 304						*	
monilis, M'Coy, Pal. Fos. p. 304			*				
obsoleta, Sow. **Pl. 9.** f. 28; **10.** f. 14; **34.** f. 11				*		*	
plana, M'Coy, Sil. Fos. p. 12				*			
tenuicincta, M'Coy, Pal. Fos. p. 304				*			
LOXONEMA elegans, M'Coy, Pal. Fos. p. 302						*	
sinuosa, Sow. **Pl. 24.** f. 3				*		*	
MACROCHEILUS elongatus, Portl. Rep pl. 31. f. 2			*			*	
fusiformis, Sow. **Pl. 10.** f. 13				*			
MURCHISONIA angulata, Sow. **Pl. 10.** f. 12				*			
angulocincta, Salt. Q. J. G. Soc. xv. pl. 13. f. 9. 10		*					
angustata, Hall, Pal. N. York, pl. 10. f. 2			*				
articulata, Sow. **Pl. 24.** f. 2				*		*	
balteata, Phil. Mem. G. S. ii. p. 358					*		
bellicincta, Salt. Q. J. G. Soc. xv. pl. 13. f. 11		*					
bicincta, M'Coy (not of Hall), Sil. Foss. pl. 1. f. 17			*				
cancellatula, M'Coy, Pal. Fos. p. 292			*	*			
cingulata, His. Pal. Fos. p. 293						*	
corallii, Sow., **Pl. 24.** f. 7						*	
gracilis, Hall, Q. J. G. Soc. xv. p. 379, pl. 13. f. 7. 8		*					
gyrogonia, M'Coy. **Foss. 40.** f. 6			*				
inflata, M'Coy, Sil. Fos. p. 15				*			
Lloydii, Sow. **Pl. 24.** f. 5					*	*	
obscura, Portl. **Foss. 40.** f. 3			*				
Pryceæ, Sow. **Pl. 10.** f. 11				*			
pulchra, M'Coy, Pal. Fos. p. 294			*	*			
simplex, M'Coy, Pal. Fos. p. 294			*	*			
subrotundata, Portl. **Foss. 40.** f. 7			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
MURCHISONIA sulcata, M'Coy (Lloydii?), Sil. Fos. pl. 1. f. 20				*			
torquata, M'Coy, Pal. Fos. p. 294						*	
turrita, Portl. Geol. Rep. p. 412			*				
NATICA parva, Sow. **Pl. 25.** f. 1						*	
OPHILETA compacta, Salt. **Foss. 27.** f. 4		*					
macromphala, M'Coy, Pal. Fos. p. 300			*				
PATELLA? Saturni, Goldf. **Foss. 40.** f. 9			*				
PLATYSCHISMA helicites, Sow. **Foss. 26.** f. 9; **Pl. 34.** f. 12		*		*		*	*
simulans, Salt. M. G. S. Expl. Sheet 32. pl. 2. f. 19						*	
Williamsi, Sow. **Pl. 34.** f. 14				*?		*	
PLEUROTOMARIA crenulata, M'Coy, Pal. Fos. p. 291						*	
fissicarina, Phil. Mem. G. S. ii. p. 357				*			
trochiformis, Portl. Geol. Rep. p. 413			*				
sp. (trochiformis, M'Coy), Sil. Fos. p. 16					*		
quadristriata, Phil. M. G. S. ii. pt. 2. pl 14. f. 4						*	
Thule, Salt. Q. J. G. S. xv. pl. 13. f. 13		*					
undata, Sow. **Pl. 24.** f. 6						*	
RAPHISTOMA aequalis, Salter. **Foss. 40.** f. 2			*				
elliptica, Portl. Geol. Rep. p. 414			*	*			
lenticularis, Sow. **Pl. 10.** f. 10			*	*			
TROCHONEMA latifasciata, M'Coy, Sil. Fos. p. 15			*				
lyrata, M'Coy. Pal. Fos p. 298			*				
tricincta, M'Coy, Sil. Fos. p. 14				*			
triporcata, M'Coy, Pal. Fos. p. 299			*		*		
trochleata, M'Coy, Sil. Fos. p. 12				*			
TROCHUS? caelatulus, M'Coy, Pal. Fos. p. 296				*			
? fucatus, Baily, G. S. Irel. Expl. Sh. 35 NE. p. 9. f. 4 (Euomphalus subsulcatus, His)			*				
? Moorei, M'Coy, Pal. Fos p. 297				*			
? multitorquatus, M'Coy, Sil. Fos. p. 15				*			
TURBO? cirrhosus, Sow. **Pl. 24.** f. 11					*		
? tritorquatus, M'Coy, Sil. Fos. p. 12				*			
Class HETEROPODA (Nucleobranchiata).							
BELLEROPHON acutus, Sow **Foss. 41.** f. 7; **Pl. 7.** f. 8			*	*			
alatus, Portl. Geol. Rep. p. 471			*				
Arfonensis, Salt. M. G. S. iii. p. 349, pl. 10. f. 6–8		*					
bilobatus, Sow. **Foss. 13.** f. 10; **Pl. 7.** f. 9; and var. compressus, Portl.		*	*	*			
carinatus, Sow **Pl. 34.** f. 8			*	*		*	
dilatatus, Sow. **Foss. 41.** f. 8; **Pl. 25.** f. 5, 6			*	*	*		
expansus, Sow. **Pl. 25.** f. 8; **34.** f. 20; **36.** f. 28				*		*	
hippopus, Salter, M. G. S. iii. p. 350, pl. 11 B. f. 2		*					
multistriatus, Salt. M. G. S. iii. p. 350, pl. 10. f. 9, 10		*					
Murchisoni, d'Orb. **Pl. 34.** f. 19						*	
nodosus, Salt. **Foss. 13.** f. 11			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
BELLEROPHON obtectus, Phil. Mem. G. S. ii. p. 356				*		*	
perturbatus, Sow. (Euomphalus tenui-striatus, Sow.; furcatus, M'Coy.) **Foss. 41.** f. 6; **Pl. 7.** f. 6, 7		*					
subdecussatus, M'Coy, Pal. Fos. p. 311				*	*		
sulcatinus, Emmons, Pal. N. Y. i. p. 32			*				
trilobatus, Sow. **Foss. 15.** f. 9				*	*	*	
Wenlockensis, Sow. **Pl. 25.** f. 7					*		
sp., Salter, Q. J. G. S. x. p. 74				*			
MACLUREA Logani, Salt. **Foss. 40.** f. 1, 1 *a*		*					
macromphala, M'Coy, Brit. Pal. Fos. p. 300		*	*				
magna, Lesueur. Pal. Fos. p. 300, pl. 1 L. f. 13		*					
Peachii, Salt. **Foss. 27.** f. 1, 2		*					
Class PTEROPODA.							
CONULARIA cancellata, Sandb. M'Coy, Brit. Pal. Fos. p. 287			*			*	
corium, Salt. M. G. S. iii. p. 355, pl. 11 A. f. 11		*					
elongata, Portl. **Foss. 41.** f. 3			*				
Homfrayi, Salt. M. G. S. iii. p. 354, pl. 10. f. 11–13		*					
lævigata, Salt. M. G. S. iii. p. 354, f. 19			*				
margaritifera, Salter, M. G. S. iii. p. 355, pl. 11 A. f. 12			*				
Sowerbyi, Defr. **Pl. 25.** f. 10			*	*	*	*	
subtilis, Salt. Pal. Fos. p. 288						*	
ECCULIOMPHALUS Bucklandi, Portl. **Foss. 41.** f. 5			*				
lævis, Sow. **Pl. 25.** f. 9				*		*	
? Scoticus, M'Coy, Pal. Fos. p. 301			*	*			
PTEROTHECA corrugata, Salt. Brit. Assoc. 1852, p. 61			*				
transversa, Portl. **Foss. 41.** f. 4			*				
THECA anceps, Salt. Mem. G. S. ii. pt. 1. p. 355					*	*	
arata, Salt. M. G. S. iii. p. 352, pl. 10. f. 15, 21		*					
bijugosa, Salt. M. G. S. iii. p. 351, pl. 10. f. 19, 20		*					
cometoides, Baily, J. G. S. Dublin, 1861, pl. 4. f. 8		*					
corrugata, Salt. Q. J. G. Soc. xx. pl. 13. f. 10	*						
cuspidata, Salt. M. G. S. iii. p. 353, pl. 10. f. 5 (Centrotheca)		*					
Forbesii, Sharpe. Q. J. G. S. ii. p. 314					*	*	
obtusa, Salt. M. G. S. iii. p. 352. f. 17	*						
operculata, Salt. M. G. S. iii. p. 351, pl. 10. f. 22, 24 (Cleidotheca)		*					
penultima, Salt. Br. Assoc. Rep. 1865, p. 285	*						
reversa, Salt. **Foss. 11.** f. 21; **41.** f. 1		*					
simplex, Salt. **Foss. 9.** f. 5		*					
triangularis, Portl. **Foss. 41.** f. 2			* ?				
vaginula, Salt. **Foss. 10.** f. 14		*					
Class CEPHALOPODA.							
ACTINOCERAS Brightii, Sow. (Orthoceras), Sil. Syst. pl. 12. f. 21					*		
nummularium, Sow. **Pl. 26.** f. 5				*	*		

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ASCOCERAS Barrandii, Salt. **Foss. 63**						*	
CYRTOCERAS approximatum, Sow. **Pl. 11.** f. 4				*			
inæquiseptum, Portl. (Phragmoceras Brateri, Portl.) **Foss. 43.** f. 1			*				
multicameratum, Hall, Pal. N. Y. p. 195		*?					
præcox, Salt. M.G.S. iii. p. 358, pl. 10. f. 2		*					
LITUITES anguiformis, Salt. Pal. Foss. App. p. viii			*				
articulatus, Sow. **Pl. 31.** f. 6						*	
? Biddulphii, Sow. **Pl. 31.** f. 5					*		
cornu-arietis, Sow. **Foss. 43.** f. 2; **Pl. 7.** f. 10; **11.** f. 1, 2			*	*			
? giganteus, Sow. **Pl. 33.** f. 1–3					*	*	
Hibernicus, Salt. **Foss. 43.** f. 3			*				
planorbiformis, Conr. Pal. N.York, pl. 84			*				
tortuosus, Sow. **Pl. 33.** f. 4					*?	*	
undosus, Sow. **Pl. 11.** f. 3				*			
sp. (cornu-arietis, Portl. Geol. Rep. pl. 28 B. f. 7)			*				
ORTHOCERAS angulatum, Wahl. **Pl. 28.** f. 4			*	*	*	*	
annulatum, and var. fimbriatum, Sow. **Pl. 26.** f. 1, 2			*	*	*		
arcuoliratum, Hall, Pal. N. York, p. 198			*				
attenuatum, Sow. **Pl. 28.** f. 3					*		
audax, Salt M. G. S. iii pl. 24. f. 7			*				
Avelinii, Salt. **Foss. 9.** f. 4		*					
baculiforme, Salt. Pal. Fos. App. p. vi						*	
Barrandii, Salt. G. J. vii. p. 177				*			
bilineatum, Hall. (O subannulatum, calamiteum, tubicinella, Portl., **Foss. 42.** f 2			*	*			
brevi-conicum, Portl. Geol Rep. p. 373			*				
Brongniarti, Troost. **Foss. 42.** f. 4			*				
bullatum, Sow. **Pl. 29.** f. 1				*		*	
canaliculatum, Sow. **Pl. 28.** f. 3					*		
centrale, His.? Pal. Fos. p. 314			*	*			
conicum, His. Sil Syst. pl. 21. f 21				*			
coralliforme, M'Coy, Sil. Fos p 8				*			
dimidiatum, Sow **Pl. 28.** f 5						*	
distans, Sow. **Pl. 26.** f. 4						*	
elongato-cinctum, Portl G. R p. 372			*				
encrinale, Salt. **Foss. 9.** f. 10		*					
excentricum, Sow Sil. Syst. p. 631					*		
filosum, Sow. **Foss. 62.** f. 1; **Pl. 27.** f. 1			*	*	*	*	
gracile, Portl. Geol. Rep. pl. 25. f. 2							
gregarium, Sow. Sil. Syst. p. 619						*	
ibex, Sow. **Pl. 29.** f. 3, 4			*	*	*	*	
imbricatum, Wahl. **Pl. 29.** f. 7						*	
incertum, Portl. Geol. Rep. pl. 28. f. 7			*				
laqueatum, Hall, Pal. N. York, p. 206			*		*	*	
lineare, Munst. Beitr. pl. 19. f. 1			*				
Ludense. Sow. **Foss. 62.** f. 2; **Pl. 28.** f. 1, 2						*	
Maclareni, Salt. **Foss. 25.**					*		
Marloense, Phil. Mem. G. S. ii. p. 353					*		
Mocktreense, Sow. **Pl. 29.** f. 2						*	
perannulatum, Portl. Geol. Rep. p. 367			*				
perelegans, Salt. (Lituites articulatus, part, and L. ibex, Sow.) **Pl. 29.** f. 5, 6					*	*	
politum, M'Coy, Pal. Fos. p. 316			*				

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
ORTHOCERAS Pomeroense, Portl. Geol. Rep. p. 370			*				
primævum, Forbes. **Foss. 62.** f. 4			*		*	*?	
sericeum, Salt. M. G. S. iii. pl. 10. f. 4, 5		*					
subgregarium, M'Coy, Sil. Fos. p. 9				*			
subundulatum, Portl. **Foss. 62.** f. 3			*	*	*	*	
tenuiannulatum, M'Coy, Pal. Fos. p. 320						*	
tenuicinctum, Portl. **Foss. 42.** f. 3			*		*		
tenuistriatum, Münst. Beitr. 3. pl. 19. f. 4				*			
textile, Phil. Mem. G. S. ii. pt. i. p. 353						*	
torquatum, Münst. Pal. Fos. App. p. vii.						*	
tracheale, Sow. (O. perelegans, Salt.?). **Pl. 34.** f. 6						*	
tumidum, Portl. Geol. Rep. pl. 28. f. 5, 6			*				
vagans, Salt. **Foss. 42.** f. 1			*	*			
vaginatum, Schlot. Q. J. G. S. vii. p. 377			*				
ventricosum, Sharpe, Q. J. G. S. ii. pl. 13					*		
ONCOCERAS, sp. **Foss. 38.** f. 6		*					
PHRAGMOCERAS arcuatum, Sow. **Pl. 31.** f. 3						*	
compressum, Sow. **Pl. 31.** f. 4				*	*	*	
intermedium, M'Coy. **Pl. 30.** f. 4						*	
nautileum, Sow. **Pl. 31.** f. 1, 2					*	*	
pyriforme, Sow. **Pl. 30.** f. 1–3						*	
ventricosum, Sow. **Pl. 32.**					*	*	
POTERIOCERAS approximatum, M'Coy, Sil. Fos. p. 10. (Orthoceras subfusiforme, O. subpyriforme, Portl.)			*				
TRETOCERAS bisiphonatum, Sow. **Pl. 11.** f. 5				*			
? semipartitum, Sow. **Pl. 34.** f. 5						*	
TROCHOLITES Hibernicus, Salt. **Foss. 43.** f. 3			*				

SUBKINGDOM VERTEBRATA.

Class PISCES.

	Primordial Silurian.	Llandeilo.	Caradoc.	Llandovery.	Wenlock.	Ludlow.	Passage-beds.
AUCHENASPIS ? ornatus (Cephalaspis), Eg. **Foss. 22.** f. 3							*
Salteri, Egert. Q.J.G.S. xiii. pl. 11. f. 4, 5							*
CEPHALASPIS Murchisoni, Egert. **Foss. 23.** f. 1							*
ONCHUS Murchisoni, Ag. **Pl. 34.** f. 1; **35.** f. 13, 14						*	*?
tenuistriatus, Ag. **Pl. 35.** f. 15, 17						*	
PLECTRODUS mirabilis, Ag. **Pl. 35.** f. 3–8						*	*
pustuliferus (Sclerodus), Ag. **Pl. 35.** f. 9–12						*	
PTERASPIS Banksii, Huxl. & Salt. **Foss. 68.** f. 2						*	*
truncatus, Huxl. & Salt. **Foss. 68.** f. 1						*	*
SPHAGODUS pristodontus, Ag. (Skin.) **Pl. 35.** f. 1						*	
THELODUS parvidens, Ag. (Shagreen.) **Pl. 35.** f. 18						*	

NOTE.—There are a few other Lower Palæozoic fossils, mentioned in this work, which are not enumerated in the foregoing Table, namely :—1st. EOZOON Canadense (**Foss. 1**), belonging to the Foraminifera and found in the Laurentian limestone. EOZOON Bavaricum is also mentioned (p. 373). 2ndly, PALÆOPYGE Ramsayi (**Foss. 2.** f. 2), one of the Trilobite family; and, 3rdly, two forms of OLDHAMIA (O. antiqua, **Foss. 3,** and O. radiata), quoted in the text as being possibly Zoophytes; some naturalists, however, doubt whether they have claim to more than a vegetable rank. These Fossils, Nos. 2 & 3, together with the Annelide-markings ARENICOLITES didymus (Salter), **Foss. 2.** f. 1, A. sparsus (Salter), HISTIODERMA Hibernicum (Kinahan), and HAUGHTONIA poecila (Kinahan), belong to the Cambrian rocks—a low zone of deposits (as explained in the text) in which scarcely any other fossil is known.

B.—*Chemical Analyses showing the absence of Phosphoric Acid in the Rocks below the Silurian Deposits* (p. 28).

In order to ascertain indirectly the presence of phosphoric acid in rocks, my valued friend Dr. Daubeny experimented upon the relative amount of produce obtained from barley sown in pulverized samples of various strata of different geological epochs. He found that, whatever the age of the rock might be, provided it belonged to a series in which organic remains were present, the amount of phosphoric acid present in the crop exceeded considerably that existing in the barley from which it was derived, indicating that the above material must have been one of the constituents of the rock, as this alone could have supplied it to the plants growing in it. On the other hand, in certain slates which lie below the oldest rocks in which many organic remains have been detected (such, for instance, as those of Nant Francon, Llanberis near Bangor, and to the north of Dolgelly, or schist taken from the foot of Skiddaw, and a sample of mica-schist from Loch Lomond), the quantity of phosphoric acid present in the crop barely exceeded that existing in the barley sown, indicating the almost entire absence of this substance in the rock itself, and consequently leading us to infer that very few organic remains could ever have existed in it, rather than that the traces of them had been obliterated by subsequent metamorphic action, inasmuch as we have no reason to suppose that any heat which might have affected the strata would have dissipated the phosphoric acid contained in them, many of the fossiliferous Silurian rocks containing phosphoric acid being equally slaty. (See Quarterly Journal of the Chemical Society of London, vol. vii.)

In subsequent researches Dr. Daubeny could detect no trace of phosphoric acid in certain specimens from the Longmynd (which fundamental rock of the Silurian region is no more altered than the overlying Silurian strata), whilst the Ludlow rocks contained as much of it as any of the younger fossiliferous rocks on which he experimented.

The determinations of the Chemist are thus in perfect harmony with the conclusions of the Geologist and Palæontologist, in establishing a decrement of life as we descend through the strata forming the crust of the globe.

C.—*Igneous Rocks of the Silurian Region of Britain compared with their German equivalents* (pp. 49 & 76).

In various parts of this volume, but particularly in the Fourth Chapter, the rocks of igneous origin, whether cotemporaneous with or posterior to the strata with which they are associated, are mentioned in terms of which German geologists must wish to know the exact import. My illustrious friend the late Baron Humboldt, who requested me to send to him a few specimens of the characteristic Silurian types of this class of rocks, has spoken of them in his fourth volume of 'Cosmos,' and also transmitted to me the following description of them as furnished by his eminent associate, Prof. Gustav Rose:—

"In accordance with your wish, I send you herewith some remarks on the rock-specimens forwarded by Sir R. Murchison. The rock-specimens termed 'greenstone,' from Pembroke, Caernarvonshire, and Anglesea, are different varieties of hypersthenite and gabbro, such as occur near Neurode in Silesia, or at the Baste in the Harz—compounds of hypersthene or diallage with labradorite, which last has become snow-white or greenish white, and then is in the incipient state of change to serpentine; the hypersthene and diallage are also

partly changed into uralite. The 'felspar-porphyry,' from Caernarvonshire, is a syenite-porphyry with imbedded crystals of felspar and mica: oligoclase and hornblende also occur occasionally in addition. This rock is connected, as to its character, with the 'syenite' of Caernarvonshire: the 'syenite' of Merionethshire, on the other hand, contains much quartz, and has a more granitic character. The 'hornblende-porphyry' is a diorite very similar to the so-called 'Tigre-ore' of Schemnitz; but where the imbedded balls of hornblende are much larger, it is more like the diorite of Raschewsk in the Ural.

"The 'ash' of Snowdon and of Bala and the 'felspathic lava' of Snowdon are varieties of the green slate: in that of Snowdon are concretions resembling those of the so-called 'fruit-slate' (*Frucht-Schiefer*) of Saxony; in that of Bala balls of hornstone occur, quite similar to the so-called felspathic lava of Snowdon, which perhaps is only a more quartzose portion of the green slate. The 'felspathic trap' of Snowdon is quartzose schist: the hollows in it, partially filled with iron-ore, are derived from decomposed included minerals, the nature of which is no longer to be ascertained. The 'felspathic ash' of Bala contains in its mass (or paste), which may be scratched with a knife, very small white crystals of felspar: it appears to be only a variety of the ordinary porphyry; but we ought to be able to see more of the rock, and to be acquainted with its geological conditions, in order to form a decided opinion on it. The 'felspathic ash' of Bishop's Castle is perhaps something similar, only more decomposed."

D.—*On Graptolites.* By W. Carruthers, F.L.S.

[The great importance of the Graptolite as a peculiarly Silurian fossil (see pages 61 &c.), and the great advance of late years in our palæontological knowledge of the various forms of this interesting organism, will render the following Note on Graptolites by Mr. Carruthers (one of the few persons who have especially studied them) of peculiar interest to the readers of 'Siluria.']

The genus Graptolithus was established by Linnæus in the first edition of his 'Systema Naturæ' for a series of natural productions which had previously been considered to be true fossils. In the genus as it appeared in the early editions of that work not a single species of the fossils to which the name is now confined was included. No alteration was introduced into the genus until the twelfth edition; and in this we find a double-celled species (G. scalaris), which Linnæus had already figured in his 'Scanian Travels.' This is the true type of the family, and the only species with which Linnæus was acquainted. The single-celled Graptolite which has by every one been referred to Linnæus's G. sagittarius, has nothing whatever to do with the organism to which he gave this name. His species is founded on a fragment of Lepidodendron figured by Volkmann; and a perusal of the characters given by Linnæus makes it evident that this figure was all the material he had for the establishment of his species. To correct this error, and to make the extent of the acquaintance which Linnæus had with these fossils more obvious, I propose to substitute for G. sagittarius the name of G. Hisingeri, after the distinguished palæontologist who first described the species, but erroneously ascribed to it the Linnean name.

The compressed condition in which Graptolites are generally found, and their somewhat anomalous structure, have caused many different opinions to be entertained regarding their nature. Linnæus considered that they were natural imitations of fossils. Bromel, and after him Brongniart, and some of the early American observers thought they were fragments of different kinds of Plants—

grasses, sea-weeds, and mosses. Walch, Wahlenberg, Schlotheim, and others referred them to Orthoceratites. Nilsson first considered them to be Polypes, and referred them to the family Ceratophyta, which included many forms that are now known to be widely removed from each other: Beck and Barrande found their nearest allies in Pennatula, M'Coy in Sertularia, while Greene, Salter, and some others would raise them much higher in the scale and place them amongst the Molluscoid Polyzoa. To complete the history, we may only mention the absurd notion of Nimmo, that they are the serrated spines of Rays, of M'Crady, that they are the larvæ of Echinoderms, and the equally absurd, although more elaborately defended, notion of Boeck, that they are torn fragments of animals of high organization.

The Graptolite may be described as a Zoophyte with a free polypary, consisting of a flexible chitinous investment, surrounding the cœnosarc and polype, or producing from its margin numerous cells which contained the polypes. The polype-cells were not cut off from the common cœnosarc by a septum. The polypary was strengthened by a slender solid axis, prolonged beyond the growing-point. The structure agrees generally with that of the Sertulariadæ; but the solid axis is an anomaly, and to some extent also the free polypary. In some Actinozoa these two characters are found; but in them the cells are hollowed out of the soft substance of the cœnosarc, and the free portion of the axis is at the proximal, and not at the distal end of the compound organism. The absence of any constriction or septum by which the individual polype was separated from the cœnosarc distinguishes them from all the Polyzoa, the individuals of which are invariably seated on a septum. On the whole they approach nearer to the Hydrozoa, having the flexible external polypary and the common cœnosarc continuous with the polypites; nevertheless they are an anomalous section of this group.

Minute specimens of several species have been figured, differing from the adult forms only in their size and in the small number of their cells. No satisfactory evidence of anything like organs of reproduction has been observed in Britain; but Hall has figured capsules attached to a double-celled Graptolite which he considers to be of this nature, and to have given origin directly to the minute forms which have been described. The only method of reproduction analogous to this among the Hydrozoa with which I am acquainted is in Tubularia, where the capsules give birth to progeny closely resembling the parents.

The geological importance of Graptolites was first pointed out in the 'Silurian System;' and nothing has since been discovered which has set aside the opinion then stated by Sir Roderick Murchison, that they were confined to and consequently characteristic of the Silurian rocks.

The increased attention that has been given to this group of fossils, and the numerous forms that have been recently discovered, have required the establishment of several new genera. Professor James Hall has described a remarkable compound form, to which he refers all the species of single-celled Graptolites, believing that the forms previously described were merely imperfect fragments. However far this may be true of the American fossils, it is certain that many, if not all, of the European species of Graptolithus are perfect organisms, their primary point and their growing termination having been observed in several species. Salter therefore properly established the genus Dichograpsus for this compound form; and the genera Cladograpsus and Cyrtograpsus contain other compound forms. Omitting those whose affinity to the Graptolites proper is yet doubtful, the following are the genera that have been found in Britain:—

A. Species with a single series of cells.

a. **Polyparies simple.**

1. **Rastrites, Barrande. Cells free throughout their whole length. Containing 3 species. Example: R. maximus, Carruthers. Foss. 90. f. 6.**
2. Graptolithus, Linn. Cells in contact throughout more or less of their length. Containing 13 species. Ex.: G. priodon, Bronn. Foss. 12. f. 3.

b. Polyparies compound.

3. Cyrtograpsus, Carr. Polypary growing in one direction from the primary point. Containing 1 species: C. Murchisonii, Carr. Foss. 90. f. 1.
4. Didymograpsus, M'Coy. Polypary growing bilaterally, and consisting of two simple or double branches. Containing 10 species. Ex.: D. geminus, Hisinger. Foss. 9. f. 8.
5. Dichograpsus, Salter. Polypary growing bilaterally and branching regularly; the non-celluliferous basis of the branches invested with a corneous disk. Containing 2 species. Ex.: D. Sedgwickii, Salter. Foss. 90. f. 3.
6. Cladograpsus, Carr. (*non* Geinitz). Polypary growing bilaterally, irregularly and repeatedly branching and rebranching, and without a central disk. Containing 2 species. Ex.: C. linearis, Carr. Foss. 90. f. 8.
7. Dendrograptus, Hall. Polypary with a thick common stem, and branching irregularly. Containing 2 species. Ex.: D. lentus, Carr. Foss. 90. f. 5.

B. Species with two series of cells.

a. With a slender solid axis.

8. Diplograpsus, M'Coy. Cells consisting of true hydrothecæ. Containing 9 species. Ex.: D. pristis, His. Foss. 10. f. 15; and Foss. 13. f. 14.
9. Climacograptus, Hall. Cells hollowed out of the body of the polypary. Containing 3 species. Ex.: C. scalaris, Linn. Foss. 12. f. 4.

b. Without an axis.

10. Retiolites, Barr. Containing 2 species. Ex.: R. Geinitzianus, Barr. Foss. 90. f. 2.

C. Species with single and double series of cells on different parts of the same polypary.

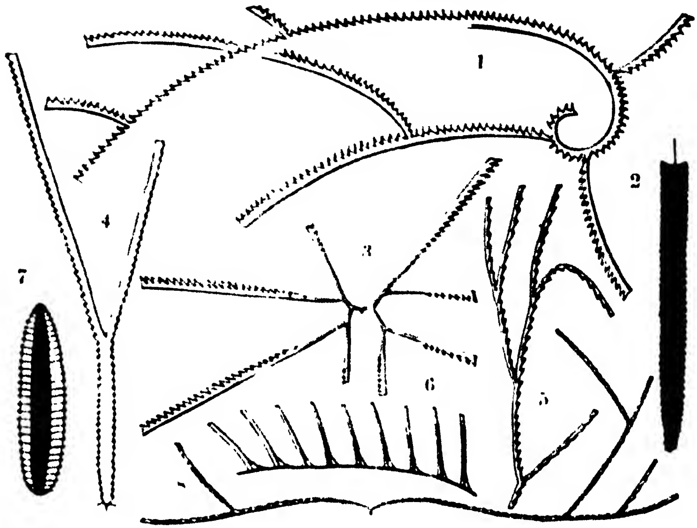
11. Dicranograptus, Hall. Containing 1 species: D. ramosus, Hall. Foss. 90. f. 4.

D. Species with four series of cells.

12. Phyllograptus, Hall. Containing 1 species: P. angustifolius, Hall. Foss. 90. f. 7.

[In noticing the Silurian rocks of Sardinia (at page 422), I omitted to remark that General Albert de la Marmora's elaborate work, 'Voyage en Sardaigne' &c. (1857), is enriched with a valuable appendix by Prof. J. Meneghini, descriptive of the fossils of that island, amongst which are many new species of Silurian Mollusks and of Graptolites, some of the latter being of very large size.—R. I. M.]

Fossils (90). The typical forms of Graptolites not elsewhere figured in 'Siluria.'



1. Cyrtograpsus Murchisonii, Carr. 2. Retiolites Geinitzianus, Barr. 3. Dichograpsus Sedgwickii, Salter 4 Dicranograptus ramosus, Hall. 5. Dendrograptus lentus, Carr. 6. Rastrites maximus, Carr. 7. Phyllograptus angustifolius, Hall. 8. Cladograpsus linearis, Carr.

E.—*Fossils of the 'Primordial Silurian Zone' of the Malvern Hills* (p. 94).

The 'Primordial' Zone of the Malverns consists (in descending order) of the Dictyonema-shales, the Olenus-shales, and the Hollybush Sandstone and Conglomerate (see pp. 94 &c.); and their fossils may be tabulated as follows:—

Fossils.	Conglomerate.	Sand-stone.	Olenus or Black Shales.	Dictyonema-shales.	Fossils.	Conglomerate.	Sandstone.	Olenus or Black Shales.	Dictyonema-shales.
Annelide-tubes		*			Cytheropsis?			*	
Scolithus	*				Lingula pygmæa ..			*	
Serpulites fistula .	*	*			squamosa		*		
Trachyderma anti-					Obolella Phillipsii			*	
quissimum		*			Salteri	*	*		
Dictyonema sociale				*	Orthis lenticularis..	*			
Agnostus princeps...			*		Spondylobolus?			*	
Turneri			*		Ctenodonta	*			
Olenus bisulcatus...			*		Lituites.....................		*		
scarabæoides			*		Theca................	*	*		
humilis			*						

F.—*Astacodermata.*

Mr. Henry Woodward has supplied the following note on the peculiar little fossils referred to at pages 133 & 134:—

With the exception of Astacoderma serratum (which is perhaps a fragment of the margin of a carapace or of a body-segment of Ceratiocaris), and of A. spinosum (not clearly referable to Ceratiocaris), the several forms of Astacoderma described and figured by Dr. Harley are doubtless founded on the teeth of Phyllopod Crustacea, such as Ceratiocaris. For examples of such teeth in Dictyocaris, an allied genus, see the 'Geological Magazine,' vol. ii. p. 401, pl. 11.

G.—*Old Red Sandstone of Forfarshire* (p. 250).

In treating of the classification and palæontology of the Old Red Sandstone of Forfarshire and other parts of Scotland at p. 250, allusion to the researches of the Rev. Hugh Mitchell was inadvertently omitted. In the Quart. Journ. Geol. Soc. vol. xvii. p. 145 *et seq.*, Mr. Mitchell describes the position of the beds of the Old Red Sandstone in the counties of Forfar and Kincardine, and at p. 146 he classifies the fossils that have been found there and elsewhere; and amongst them he enumerates the small spores known as Pachytheca, which are not rare in the uppermost Silurian beds at Ludlow in Shropshire.

In addition to the references made at p. 251 &c. to Mr. Powrie's discoveries, it is right to refer the reader to the publications of this author on the Old Red Sandstone and its fossils, in the Quart. Journ. Geol. Soc. vol. xvii. p. 534 *et seq.*, and vol. xx. p. 413 *et seq.*

H.—*Caithness Flagstones of the Old Red Sandstone* (p. 258).

The Flagstones of Caithness, which were first described by me in the year 1827, under the name of 'Bituminous schists' (Trans. Geol. Soc. 2nd ser. vol. ii. p. 213), are in many places impregnated with bitumen, chiefly resulting from the vast quantity of fishes imbedded in them. Their most durable and best qualities as flagstones are derived from an admixture of this bitumen with finely laminated siliceous, calcareous, and argillaceous particles, the whole forming a natural cement more impervious to moisture than any stone with which I am acquainted.

The following analyses of several specimens of Caithness flagstone and the accompanying bituminous shale, from the celebrated quarries of Castle Hill, belonging to my friend Mr. G. Traill, M.P., are indeed of high value, having been prepared under the superintendence of that distinguished chemist Dr. Hofmann.

These results completely sustain the opinion I was led to form upon the spot, that the peculiar tenacity and durability of these flagstones is due to the manner in which the silica and alumina are cemented together by certain proportions of calcareous and bituminous (organic) matter.

Mineral analysed.	Silica and Silicates insoluble in H Cl.	Oxide of Iron and Alumina.	Carbonate of Lime.	Organic matter.	Water, loss at 100° C.	Salts of Magnesia, the Alkalies, &c.	Total.
No. 16. Top flag	68·40	10·21	10·93	3·88	0·42	6·16	100·00
No. 7. Middle flag	69·45	11·50	10·66	5·79	0·40	2·20	100·00
Bituminous Shale	69·96	8·15	7·72	10·73	0·53	2·91	100·00
No. 1. Bottom flag	61·39	4·87	21·91	3·40	0·20	8·23	100·00

In analyzing a portion of the bituminous schists from the property of the Earl of Caithness (near Barrogill Castle), Dr. Hofmann reported to me as follows:—"When submitted to the action of heat, this substance evolves a considerable amount of gas, and likewise of oily matter containing a certain proportion of ammonia. The residue which remains behind is a greyish mass, consisting essentially of silicate of alumina (clay) mixed with a certain quantity of sesquioxide of iron and of sulphate of lime. A very minute proportion of phosphoric acid was likewise found to be present. The loss which the mineral undergoes on heating was found in two consecutive experiments to be 30·21 and 30·02; so that the mineral may be said to contain in round numbers—

Fixed matter (mineral)	70
Volatile matter (organic)	30
	100

"In determining the amount of gas furnished by the distillation of the mineral, a portion of it was heated in an iron tube, in order to imitate, as nearly as possible, the circumstances of an operation on a large scale. In two consecutive experiments which were performed in this manner, the following results were obtained:—

		Cub. centim.
I	100 grammes furnished	7690
II	" " "	7430
	Mean	7560

"Assuming 100 grammes of the mineral to yield, on an average, 7500 cubic centimetres of gas, a ton of the material would furnish 2690 cubic feet. The ordinary varieties of coal used in gas-making yield from 8000 to 10,000 cubic feet of gas per ton. The gas obtained from the mineral is very luminous; it is nearly entirely free from sulphur, and it is on this account very readily purified. The residue left in the retort after the expulsion of the gas retains but a small amount of carbon, viz. 8·5 per cent.; this residue, therefore, has but little value as coke.

"The mineral in question is in no way related to ozokerite, as has been suggested. From that substance it may be at once distinguished by its infusibility (ozokerite fuses at 80° C.= 176° Fahr.), and by its entire insolubility in alcohol and ether, in which solvents ozokerite dissolves, although with difficulty."

I.—*Fossil Reptiles in the Carboniferous Shales of Ireland.*

For a full account of the remarkable evidences of Reptilian life having flourished in the Carboniferous period, referred to at p. 303, see the memoir 'On a Collection of Fossil Vertebrata, from the Jarrow Colliery, County of Kilkenny, Ireland,' by Thomas H. Huxley, F.R.S. &c., and E. Perceval Wright, A.M. &c., Transactions Roy. Irish Acad. vol. xxiv. 1867.

K.—*Spitzbergen* (pp. 323 & 368).

Since Chapter XIV. was printed, I have perused with much interest an excellent sketch of the geology of Spitzbergen by Mr. A. E. Nordenskiöld, resulting from the examination of the late Swedish Scientific Expedition*. He sub-

* Sketch of the Geology of Spitzbergen by A. E. Nordenskiöld: Stockholm, 1866. (Transactions of the Royal Swedish Academy of Sciences.)

stantiates the fact that, although fragments of rock with true Permian fossils have been found in detached blocks on the adjacent 'Thousand Islands,' the fossils described by M. de Koninck are not, as was supposed, of Permian age, but are true Carboniferous species which abound largely in the Mountain-limestone of that Arctic tract. This formation, surmounted by Triassic and Jurassic rocks, reposes on unfossiliferous red and green ferruginous slates and conglomerates, which lie upon clay-slates, quartzites, and limestones, also devoid of fossils, and these rest on vertical strata of micaceous and hornblendic slates with bands of quartzite, crystalline limestone, and dolomite. Now, as all this great series is based upon gneiss and granite, we may not unreasonably infer that Spitzbergen in itself may be found to contain not only, as the author suggests, the equivalents in time of the Devonian and Silurian, but also the representative of the Laurentian rocks.

L.—*Conodonts of Pander* (pp. 134 & 356).

"*On the Lower Silurian organisms called 'Conodonts' by Dr. C. H. Pander* *.—Minute, glistening, slender, conical bodies, hollow at the base, pointed at the end, more or less bent, with sharp opposite margins, might well be lingual teeth of Gasteropods, acetabular hooklets of Cephalopods, or teeth of Cartilaginous Fishes.

"Against the latter determination is the minute size of the bodies called 'Conodonts' by Dr. C. H. Pander. Their basal cavity doubtless contained a formative pulp; but the proof that the product of such pulp was 'dentine' is wanting: the observed structure of the hooklet presents concentric conical lamellæ of a dense structureless substance containing minute nuclei or cells.

"In some specimens the base is abruptly produced, and divided from the body of the hooklet by a constriction,—a form unknown to me in the teeth of any Fishes, but presented by certain lingual teeth of Gasteropods, *e. g.* the lateral teeth of Sparella. In other Conodonts the elongated base is denticulate or serrate, as in the lateral teeth of Buccinum and Chrysodomus. It is improbable, however, that they belong to any conchiferous toothed mollusk, the shells of such being wanting in the deposit where the Conodonts are most abundant.

"The more minute hooklets have a yellowish transparent horny appearance: the larger, perhaps older ones, present a harder whitish appearance. Their analysis by Pander yielded 'carbonate of lime,'—carbonic acid being evolved by the application of dilute nitric acid, and oxalic acid producing an obvious precipitate.

"The detached condition of the hooklets and the integrity of the thin border of the basal pulp-cavity indicate that they have not been broken away from any of those kinds of attachment to a bone which the minute villiform teeth of osseous fishes would show signs of. The Conodonts have been supported upon a soft substance, such as the skin of a Mollusk or Worm, the mucous membrane of a mouth, or throat, or proboscis: but, to select the teeth of Cyclostomous or Plagiostomous Fishes as the exclusive illustration of the above condition, is to take a partial and limited view of the subject.

"In comparing the Conodonts with the teeth of Fishes, they present, as Dr. Pander recognizes, the closest resemblance, in that class, with the conical, pointed, horny teeth of Myxinoids and Lampreys; and the absence of any other hard part in the strata containing the Conodonts tallies with the condition of

* 'Monographie der fossilen Fische (Unter-Silurische Fische, Conodonten),' 4to, 1856.

the Cyclostomatous skeleton, but not more than it does with the like soft condition of Annelidous Worms and Naked Mollusks. But the teeth of all known Cyclostomes are less varied in form than are the Conodonts. Certain lingual plates of Myxinoids are serrate, but not with a main denticle of much greater length, such as shown in the form of Conodont called Machairodus by Pander. Most Cyclostomous teeth are simple thick cones, with a subcircular base: and every known tooth of a Cyclostomous Fish is much larger than any of the forms of Conodont, which rarely equal half a line in length. This minuteness of size, with the peculiarities of form, inclines me strongly to refer the Conodonts to some soft Invertebrate genus. Certain parts of small Crustacea, *e. g.* the pygidium or tail of some minute Entomostraca, resemble in shape the more simple Conodonts: but when we perceive that these bodies occur in thousands, detached, with entire bases, and that any part of the carapace or shell of an entomostracan or other crustacean has rarely been detected in the Conodont beds, it is highly improbable that they can have belonged to an organism protected by a substance as susceptible of preservation as their own substance. Much more likely is it that the body to which the minute hooklets were attached was as soluble and perishable as the soft pulp upon which the Conodont was sheathed. I find no form of spine, denticle, or hooklet in any Echinoderm, and especially in any soft-bodied one, to match the Conodonts, and conclude that they have most analogy with the spines, or hooklets, or denticles of Naked Mollusks and Annelides.

"The formal publication of these minute ambiguous bodies from the oldest fossiliferous rocks as evidences of fishes is much to be deprecated."—RICHARD OWEN, *British Museum, Nov.* 18, 1858.

M.—*Silurian Fossils of Anticosti* (p. 436).

The Silurian Fauna of Canada has recently been much enriched by the researches of the Colonial Surveyors and by admirable descriptions, by their Palæontologist, Mr. E. Billings, of the remains found in the great Island of Anticosti at the mouth of the River St. Lawrence *.

The Zoophytes, Mollusks, and Crustaceans collected in the greater part of the island, and amounting to 121 species, present an eminently Lower-Silurian aspect; and whilst 85 of this number are new to geologists, 36 species are common European and North-American types. Thus among the latter we find the widely spread Brachiopods Leptæna sericea, Orthis testudinaria, and O. lynx, as well as Bellerophon bilobatus, associated with Calymene Blumenbachii.

The fossils in the overlying strata of the same island have been referred by Mr. Billings, after careful comparison and correlation, to the Llandovery rocks of my classification, or what he terms Middle Silurian.

With the following just and philosophical remarks of this author I entirely agree; for they are as true in reference to the Silurian rocks of North America as they were proved to be in Bohemia by M. Barrande. Commenting upon the difficulty (if not impossibility) of correlating all the Silurian divisions of Britain with those of America, he thus writes:—"From what we know of the origin and mode of accumulation of sedimentary strata, it is highly improbable that each of the minor formations of one country should have its exact equivalent in another land several thousands of miles away, although the larger groups, of which these smaller ones are the component parts, may be well paralleled and

* Geological Survey of Canada: 'Catalogue of the Silurian Fossils of the Island of Anticosti,' by E. Billings, 1866.

represented in a general way. Everywhere we find a number of breaks or gaps, and the probabilities are vastly against these having been all occasioned at the same time in distant localities."

I rejoice to see this sentiment confirmed by eminent palæontologists of distant countries. As to the numerous breaks which were ably pointed out by Professor Ramsay in the Silurian series of England, Mr. Billings also treats of these in North America. Now it is well known to every practical geologist that such breaks run through every great series or system of rocks, whether Palæozoic, Secondary, or Tertiary; and therefore it is evident that perfect parallelism of the minor groups of distant countries can only be looked for as exceptions, and not as the rule.

It further appears from the writings of Mr. Billings, that the base of the 'Primordial' Silurian Zone of Barrande, seen in the slates and schists near Boston and in Minnesota and Wisconsin, has not been found in Canada, and that what has there been called 'Potsdam Sandstone' is of somewhat more recent age (see the Table, p. 446–7).

N.—*Palæozoic Rocks of Illinois in the United States* (p. 427 *et seq.*).

The work entitled 'The Geological Survey of Illinois,' as carried out under the direction of Mr. A. H. Worthen, assisted by Professors Whitney and Lesquereux and Mr. H. Engelman, which reached me after the Chapter on America was completed, gives a well condensed and clear account of the whole series of rocks in that highly prosperous young State.

The Lower Silurian of these authors consists of Lower Magnesian Limestone, covered by the St. Peter's Sandstone, the Galena and Trenton Limestones, and the Cincinnati group of strata overlying them.

The Upper Silurian consists of the Niagara (or Wenlock) Limestone, and a superior deposit called Clear-Creek Limestone. The Devonian rocks are made up of Oriskany Sandstone, the 'Devonian Limestone,' and 'Black Slate.'

The Lower Carboniferous ('Infra-carboniferous') exhibits five stages, including one of limestone. It is surmounted by conglomerate (Millstone-grit) and Coal-measures.

In the second volume the organic remains, chiefly those of the Carboniferous system, are elaborately described, with many plates.

O.—*Minute Silurian Fossils in America* (p. 446).

Among the fossils of the Silurian rocks might be mentioned the microscopic organisms discovered by Dr. M. C. White in nodules of hornstone, occurring plentifully in the Black-river Limestone (as well as in some Devonian limestones) of North America. These little fossils are apparently Desmids and Diatoms, Sponge-spicules, and fragments of the teeth of Gasteropods; and, in the case of the microphytes above-mentioned, "they carry back to a very early epoch forms of life which have hitherto been looked upon as belonging only to a much more recent era in the life of our planet."—American Journ. Sc. Arts, May 1862, and Geologist, vol. v. p. 239.

P.—*Produce and Relations of the Gold-mines near Dolgelly, Merionethshire* (p. 450).

The mine of Clogau is the property of the Crown; and owing to the obliging

information of the Hon. James Howard, the Chief Commissioner of Woods and Forests, I am enabled to state as follows.

This mine, which produced in the latter half-year of 1860 a profit of £163 only, gave gold to the value of £6030 in 1861; and in the year 1862 the yield rose to 24,066 (6181·126 oz. of gold from 620¾ tons of vein-stuff). In 1863 the profit was £2257; in 1864 it was £9061; in 1865 £2320; and only £512 in 1866. In the present year, however, there has been a great increase in the produce,—£1920 having been realized according to the accounts for the first half-year, whilst £1900 is the estimated produce in the succeeding month.

A very recent examination of the gold-bearing quartz-lodes in the neighbourhood of Dolgelly by Mr. David Forbes, led him to consider that these lodes are seldom or only faintly auriferous, except when they cut through the Lower Lingula-flags of that district.

From the explorations hitherto made, it appears that where these lodes had been worked deeper into the Cambrian grits they turned out to be sterile, or to contain merely traces of gold. There further appeared to Mr. D. Forbes to be an intimate connexion between the auriferous deposits and the intrusive rocks (probably diabase) of the district, marked as 'greenstones' on the Geological Survey Map: the richer parts of the Vigra and Clogau gold-mines occurred where the lode, in cutting through the Lower Silurian strata, had encountered such rocks.

Q.—*Eozoon in a Calcareous condition* (p. 13).

Since the text was printed, a specimen of Eozoon Canadense, examined by Principal Dawson and Dr. Carpenter, has been found wholly composed of carbonate of lime, as is the case with most fossils, without the serpentinous materials that so much resemble asbestiform and other minerals as to mislead some observers. This specimen, showing characters that correspond with those in the serpentinous specimens, was found in the Laurentian rocks at Tudor, Hastings County, Canada West; and it seems to have been a young individual, broken off and buried in calcareous mud which has become a micaceous limestone (or calcareous schist), on the surface of a layer of which it lies exposed by weathering.—Canadian Geol. Survey, Report of Progress, 1866, pp. 17 &c., and Geol. Soc. London Proceedings, May 8, 1867.

R.—*Foraminiferal Character of the Silurian Stromatopora* (p. 218).

In connexion with the occurrence of such Foraminifera of a large size as Eozoon in the oldest known rocks, it is well to keep in view that Receptaculites has apparently some curious points of alliance with the Foraminifera (as indicated by Mr. Salter), and that, in support of Principal Dawson's suggestion that some of the obscure zoophytic forms (such as Stromatopora) in the Silurian rocks might prove to be Foraminifera also, Dr. Carpenter finds good grounds to remark as follows (in a letter to Professor Rupert Jones):—

"Burlington House, June 12, 1867.

..... "I have examined all your specimens of Stromatopora [S. striatella, from the Wenlock beds], and do not find any of them in good condition for showing the structure. The shell-walls (?) have undergone a change into crystalline calcite, and are not clearly differentiated from the matrix which fills the cavities. In this respect, however, the condition of these fossils corresponds closely with that of Palæozoic Foraminifera in general, such as the Fusulina

of the Carboniferous Limestone. Looking to the general arrangement of the chambered structure, I can entertain no doubt that the true Stromatopora, as represented by the specimens you have placed in my hands, is a Foraminiferal organism."

Dr. Carpenter has also carefully examined a portion of the specimen figured in Plate XLI. fig. 32 (named 'Stromatopora nummulitisimilis' in the Sil. Syst.), and he corroborates the statement given in the last edition as to its oolitic nature; for he finds it to be unmistakeably pisolitic, being formed of small concentric calcareous nodules, imbedded in a matrix consisting of comminuted shells and other organisms.

S.—*A New Theory of several former Glacial Periods* (p. 505).

In the concluding pages of this work a brief allusion only has been made to what I term the great glacial period, which some geologists believe was divided into two epochs, separated from each other by a long lapse of time, during which a rich vegetation flourished, and when, according to certain writers, man himself existed. Recently, however, this theory, founded on the changes in the obliquity of the ecliptic, has been ingeniously extended by Mr. Croll to what I cannot but consider much beyond its legitimate application when he speaks of evidence of ice-action during the Devonian and Silurian epochs! In fact, great length of time being allowed, his theory may be applied during all geological periods.

Now this view is entirely antagonistic, as respects the Palæozoic eras, to the facts and reasoning brought forward in this volume. The wide, if not universal spread of the same marine animals during the Silurian epoch, and the similarly broad extension of the same land-plants in the Devonian and Carboniferous epochs, are all evidences of the then prevalence of a mild and equable temperature. In those early periods when the same groups of animals were so widely diffused, there could have been no lofty mountains and equivalent deep seas, inasmuch as the latter would have operated as positive barriers to such wide extension of marine creatures.

If there did not then exist that great variation of outline which became dominant in the Tertiary times and has increased in our epoch, and if in the Palæozoic ages low or moderately high tracts of land alone prevailed, I have yet to learn what cause could then have operated to bring about a great extension of glaciers like that which really took place at the close of the Tertiary period, when the loftiest mountains had been raised up, the cold climate being directly coincident with such elevations of vast masses of land and extensive sea-bottoms. Admitting for a moment the applicability of this theory of Mr. Croll, would not, I ask, the intervention of ice-action in warm, humid, and equable periods have left some traces in the natural-history products of such colder fits? Ought we not to meet with some animals and plants indicative of such cold climates? But as no signs of this sort have been detected in Palæozoic rocks, I cannot admit that a few striated stones or erratic blocks detected at wide intervals only in some old conglomerates, can in fairness be adduced as indications of such grand and general changes of climate in those olden days, when the seas of our planet and its lands contained, as far as observation goes, no living thing which does not bespeak a moderate and moist if not a warm climate.

On this point, indeed, my own view is supported by the opinion of Sir Charles

Lyell. In his last concluding remarks on climate, and after showing that a "warm, humid, and equable climate" must have prevailed in Palæozoic times, he, alluding to the indications that have been discovered of intervening glacial action in the Miocene, Eocene, and Permian eras, makes this pertinent reflection:—"but no decided changes in the character of the organic remains have yet been shown to accompany the inorganic proofs of supposed glacial action of these remoter periods."—Principles of Geology, 10th Ed. (1867), vol. i. p. 232.

Now, if so good an authority seems to doubt the validity of the evidence of glacial action in the Eocene and Miocene eras, when the surface of the earth or the relations of land and water had much approximated to their existing outlines, how infinitely more must we demur to glacial action in the Primary ages, when a warm, humid, and equable climate prevailed so generally!

For these plain reasons I demur to the extension of the ingenious reasoning of Mr. Croll as founded upon the glacial phenomena of the Arctic and Antarctic regions, and I submit that it cannot be applied to the enormous areas which were under water or raised into moderately lofty lands in Palæozoic times.

At the same time I willingly grant that there may be much force in his reasoning when applied to regions within the influence of the poles. In short, I bow to the opinion of Sir John Herschel *, "that the very considerable extent to which in immensely long periods the oscillation in the eccentricity and inclination of the ecliptic, combined with movement of the apsides, may affect our climates, must be very influential upon the quantities of ice and extent of glacial production."

Notwithstanding my scepticism as to the existence of glaciers and extensive glacial action during any period anterior to Tertiary times, I think it right to state that the examples of erratic blocks of granite and greenstone in the Chalk of Croydon †, and of a drifted block of coal in the Chalk of Kent ‡, may be rationally accounted for by the supposition that they were carried southwards by shore-ice floating from the Arctic regions.

There is another part of Mr. Croll's paper which must sadly disturb the convictions of geologists who have referred the presence of sea-beaches and marine shells at different heights to successive elevation of shores and sea-bottoms. He, on the contrary, is disposed to refer them to great periodical rises of the sea-level, due to the melting of vast masses of ice. But such a cosmical theory, however ingenious, cannot be allowed to overbear geological induction based upon numberless well-ascertained proofs of elevations of the land. In short, all geologists, as far as I know, subscribe to the truth of the apparently paradoxical aphorism of my old friend Greenough, "stability of the waves, mobility of the land."

T.—*The Silurian Passage-beds in Shropshire* (pp. 139 &c.).

The details of a very interesting section of the Upper Silurian Passage-beds, with the two Bone-beds in place, at Linley in Shropshire, were given by the late Mr. G. E. Roberts and Mr. J. Randall in the Quart. Journ. Geol. Soc. vol. xix. p. 229; and in the same volume, p. 233, Mr. Roberts described and illustrated some tracks of Crustaceans or Fishes in the Passage-beds near Ludlow.

* Letter to myself, June 9, 1867.
† Quart. Journ. Geol. Soc. vol. xiv. p. 252.
‡ Ibid. vol. xvi. p. 326.

U.—*The Occurrence of Eozoon Canadense in Limestone of the Laurentian System in Finland* (pp. 13 &c.).

In the Bulletin de l'Acad. Impér. des Sciences de St. Pétersbourg, vol. x. No. 1, p. 151, Prof. Pusyrewski describes the occurrence of Eozoon Canadense in the limestone of Hopunwara in Finland. He describes the rocks in the Government of Wiborg and vicinity as consisting of:—a great lower series of orthoclase-gneiss and hornblende-rock; and an upper series of gneiss and schists, divisible into two groups, in the lower beds of each of which are bands of marble. The limestone (at Hopunwara) of the lower of these two subdivisions contains serpentinous bands, granules, and filaments, which Prof. Pusyrewski recognizes as being Eozoonal in structure, and exactly similar to those described by Logan, Dawson, and Carpenter, proving that these rocks of Finland correspond in the main to the Laurentian system of Canada.

V.—*Lingulella in the Upper Cambrian Rocks of St. David's* (pp. 24 &c.).

At the Meeting of the Geological Society on June 19th, 1867, Mr. J. W. Salter read an account of the discovery of a minute Lingulella in the red Cambrian rock of St. David's, which there underlies the 'Primordial Silurian' (*mihi*). According to my view (and I am entitled to judge by acquaintance with both districts) the rock in which this small fossil was found may be paralleled in age with the uppermost or red portion of my original 'Cambrian' of the Longmynd (1835). This unique Lingulella is pronounced by Mr. Salter to be of the same species as one commonly found with Paradoxides in the zone which I term 'Primordial Silurian,' viz. L. ferruginea (Salt.); but Dr. Hicks distinguishes it as *var.* ovalis.

INDEX.

[The fossils here enumerated are those illustrated by figures in the text.]

THE END.

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